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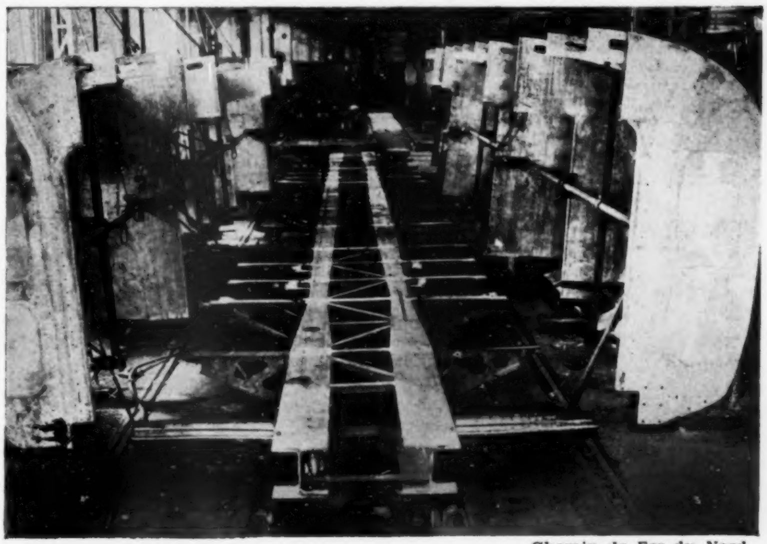
Progress in the Development and Application of Aluminium and Its Alloys

By G. A. ANDERSON, B.A.

The commercial career of aluminium only extends over a period of about 50 years, but in that short time its application has achieved fifth place in the family of metals. The rapid expansion in the use of this metal is due, largely, to patient research work in this and other countries. In this article the author discusses the production of super purity aluminium, alloy improvements, free-cutting alloys, improved forgings, better casting alloys, aluminium reflectors, and concludes with a reference to the value of aluminium as an alloying element.

THE only sound basis for industry is now universally recognised as research followed by production, as opposed to the older conception of production in spite of research. The aluminium industry was particularly fortunate in being born only shortly before this enlightened era, as there was then insufficient time for the breeding of many practices hallowed only by tradition, but nevertheless almost incredibly difficult to eradicate. New ideas have been put into operation with the least possible delay, and progress has been extremely rapid. We have just celebrated the fiftieth anniversary of the discovery of the only really economic method of production, the Hall-Herault electrolytic process ; it is therefore a very appropriate occasion for reviewing the progress that has been made. It is hoped to show by some outstanding examples how recent research and development work have resulted in improved metals and improved methods, and how these together have, in turn, combined to evolve new uses for aluminium and its alloys.



Chemin de Fer du Nord.

Fig. 1.—Arc welded sides for passenger coach in 7% Mg alloy, still in welding jigs, ready for assembly on to lightweight steel underframe.

Super Purity Aluminium

Alloy developments during the last twenty years have been so remarkable that the progress made in the production of aluminium itself has perhaps been somewhat overlooked. The metal originally produced in the reduction cells was not of particularly high purity, and producers were faced with two alternatives—either to improve the purity of the metal as formed in the cell, or to refine it afterwards.

By careful attention to every stage of the chemical process for refining the ore, to electrolytes, and to the selection and preparation of carbon materials, the commercial grades of aluminium have been improved to better than 99%, while, for special purposes, it is now possible to produce as high as 99·8%. It seems probable that this represents very nearly the practical limit for reduction furnace metal and for the bulk of requirements it is very doubtful whether anything is to be gained by a further increase in purity. For special purposes, however, still purer aluminium appears an attractive proposition, and a great deal of research has been devoted to methods for refining outside of the reduction cell proper.

Separate refining processes depending on both physical and chemical principles were advocated in the early days, but it was not until Hoopes, in America, developed an electrolytic method that real progress could be made. Although first announced at the beginning of the century, about 20 years elapsed before the process had been sufficiently perfected to warrant operation on a commercial scale. From 1922 onward, metal of 99·95% purity could be produced, but the bath was not at all easy to control ; other workers, notably the French aluminium producers, have improved the process in respect of both ease of working and metal quality, and it is now possible to produce regularly metal of 99·99%, while as high as 99·998% has been reached on occasions.

This super-purity aluminium is now being produced in this country. Mechanically, it behaves much as would be

expected from the study of other very pure metals. It is about 25% weaker than 99·5% metal, and substantially more ductile. It work-hardens very much less rapidly; it is, in fact, possible to produce sheet by cold rolling from the billet without annealing. The electrical conductivity is about 65%, as compared with the standard 60·6%.

It is on the chemical side that the outstanding differences appear, super-purity metal exhibiting extraordinary resistance to corrosion by the atmosphere and many reagents, mostly acid, highly destructive to normal aluminium. The manufacture of specially corrosion-resistant or ductile alloys, using super-purity aluminium, also seems to have interesting possibilities. This very high-grade metal is necessarily rather expensive, and it is still too soon to say just where the extra cost can be justified; extensive trials are, however, being undertaken and are expected to lead to a regular market for an appreciable tonnage.

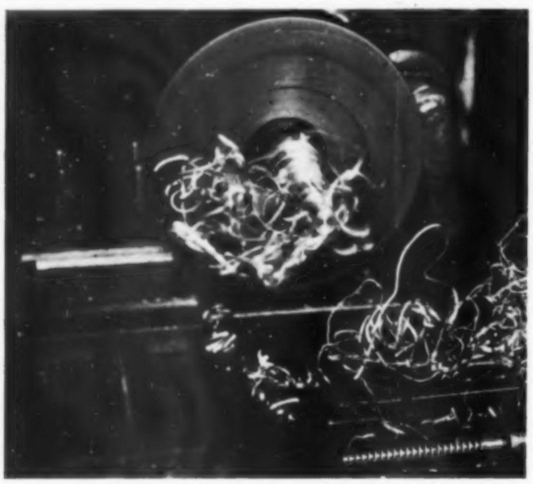
Alloy Improvements

In the strong alloy field the demand for strength with lightness and the growing competition from special alloy steels on the one hand and magnesium rich alloys on the other, constitute a powerful stimulant for research. Improved heat-treated alloys have been developed, giving, in wrought form, some 30 tons tensile, 23 tons proof stress, and 10% elongation. These still depend on the hardening effect of copper with magnesium and silicon, and represent refinements in well-established materials rather than radical innovations.

One of the clearest justifications for the enormous amount of time and money now spent on research is the frequency with which old ground can be profitably re-explored in the light of modern experience, and using modern methods. An interesting patent* has appeared showing the result of applying this process to wrought alloys based on the addition of zinc to aluminium. During the war period the late Dr. Rosenhain and his co-workers at the National Physical Laboratory showed that it was possible, using an alloy containing 20% Zn, 2·5% Cu, 0·5% Mn, 0·5% Mg, quenched from 350° C., to produce wrought material having 37 tons tensile and 32 tons yield. The alloy was, however, difficult to work, and had low shock-resistance and other disadvantages, sufficiently serious to prevent its commercial exploitation. The new alloys can be typified as containing 8–14% Zn, 1·5–5% Cu, 0·1–3% Ni, with controlled additions of Mg, Fe, Si, and Ti. Forged bar after heat-treatment is claimed to have the following properties: 38 tons tensile, 32 tons yield, 10% elongation, 200 Brinell hardness. The commercial development of these materials will be watched with interest, and will show whether, with the new composition and up-to-date technique, the disadvantages of the earlier material have now been overcome.

* B.P. 448,929.

Another excellent instance of the new methods having improved old materials is to be found in the aluminium-magnesium series. These were first introduced many years ago under the name of Magnalium, but manufacturing and fabricating difficulties proved too great for the technique then available. The series is, however, now coming into its own, and practically all compositions between 2 and 10% Mg are being exploited commercially, very frequently with small additions of other metals, such as manganese and chromium. From 2–5% Mg may be classed as medium strength alloys, and fill the demand for a moderately priced material, giving, without the complication of heat-treatment 12–20 tons tensile with good ductility. They can be welded, and are relatively stronger after welding than are heat-treated materials. Their corrosion resistance is outstanding, particularly under salt-water conditions. They seem to be the logical choice where comparatively rugged construction is required, and for such things as railway passenger coaches, ships' boats, and yachts, where, owing to seating requirements and the necessity for providing entrances, windows, gangways, etc., design is largely decided by practical considerations, and consequently rather more metal often employed than is theoretically necessary.



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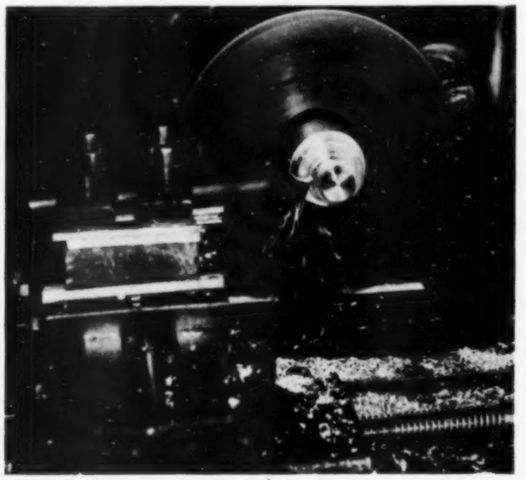

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Fig. 2.—Normal and freecutting aluminium alloys in the same tool set up.

Rolled alloys containing 7% Mg have mechanical properties practically equal to Duralumin, while retaining the other advantages of their class. They are, furthermore, about 6% lighter than the general run of heat-treated alloys. The limit of solid solubility for magnesium is not reached until 15% Mg, but, although undoubtedly strong, alloys near the top of the range seem to lack ductility and are excessively difficult to work in the "as rolled" condition. Special heat-treatments are now being developed to ensure that a more complete solid solution is obtained, and the resulting effect on mechanical properties is remarkable.

Alloy.	As Rolled.			Solution Heat-treated at 450° C.		
	U.T.S.	Yield.	Elongation.	U.T.S.	Yield.	Elongation.
9% Mg.	30	26	10	23	12	29
12% Mg.	37	22	5	26	14	27
15% Mg.	17	16	0	30	17·5	15

These homogenised alloys are not yet available commercially, but if and when they become so they should be found particularly suitable for pressing and drawing complicated shapes, such as those required for aircraft construction.

Free-cutting Alloys

Aluminium alloys in cast form are well known for the ease and speed with which they can be machined, this factor frequently bringing the cost of a finished aluminium casting almost down to that of a finished iron one, although the cost per pound of the former is at least four times as great. Wrought alloys have not achieved the same reputation, for the bulk of wrought material for machining purposes is required in the form of rod stock for automatic and repetition machinery, and aluminium alloys have been prevented from competing seriously in this market owing to their lack of free-cutting properties. Research has now succeeded in producing alloys that can be machined at the same speeds and with much the same tools as free-cutting brass, while giving short, curled chips, easily washed clear of the work. This has largely been achieved by adding one or more of the metals—lead, tin, antimony, and bismuth—to alloys of the Duralumin type, but in Germany aluminium/magnesium alloys have also been rendered free-cutting by special heat-treatments and additions of chromium and titanium. These free-cutting alloys, with their light weight, white colour, and good corrosion resistance, are expected to open up entirely new markets for aluminium products.

Improved Forgings

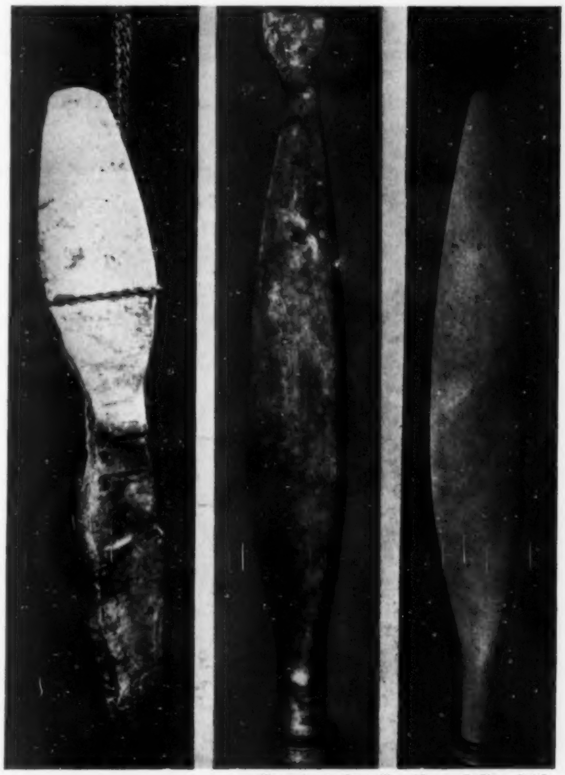
The quality of alloys for forging purposes has been steadily improved, while tremendous strides have been made in technique following a more complete understanding of the hot-working characteristics of these materials. The forging of aeroplane propellers affords a striking example of the difference between methods of only five years ago and those of to-day. The rough forging of the propeller for the 1931 Schneider Cup winner was a rather cumbersome affair, in which the pitch and chord of the blades were only roughly indicated, and no attempt was made to give them aerofoil section ; it weighed some 350 lb. in the rough, and only 85 lb. when finished, these figures showing exactly how much had to be left to machining.

Contrast with that the other forged blades illustrated, which are now being produced in large numbers for variable pitch air-screws. The die embraces the whole length of the blade and is so arranged that an approximately constant deformation takes place at all points during the final forging operation, thus eliminating discontinuities in the macrostructure. The forging is made true to pitch and track, and any cross-section is a perfect aerofoil. It carries, in the " as-forged " condition, the steel thrust race rings retained by an up-ended flange. The macrostructure is so controlled at all points that it continues to run parallel to the surfaces after machining, a point of great importance where heavy alternating stresses are involved. As can be seen, the rough forging conforms very closely to the finished product, actually keeping within about $\frac{1}{16}$ in. per side. The weight of the forging is 96 lb. as delivered, and the weight of the finished blade 70 lb., which includes boring the shank for about 18 in. of its length.

Better Casting Alloys

The discovery that the modified 12% silicon alloys, such as Alpax, can be rendered heat-treatable by small additions of magnesium and manganese, has made possible the development of casting alloys retaining the advantages of the older materials, but having greatly improved mechanical properties. These new alloys offer a combination of high strength, low specific gravity, corrosion resistance, and ease of casting, at present unrivalled. Attention is now being devoted to developing similar alloys for wrought purposes, particularly for forgings, where their behaviour under conditions of plastic flow has been found to be particularly satisfactory.

The strength and elasticity of aluminium alloy castings have been steadily improved, it now being possible to obtain a sand-cast bar giving 22 tons ultimate and 20 tons proof stress ; a corresponding increase in elongation and shock resistance has still to be achieved. One type of alloy is, however, outstanding in these respects. A straight 10% magnesium alloy, sand cast and solution heat-treated, will give 19 tons ultimate, 11 tons proof stress, and 13%



Courtesy Jas. Booth and Co., Ltd.

Fig. 3.—Duralumin forging for 1931 Schneider Cup winner.

Fig. 4.—Modern die-forged blades in Duralumin.

elongation ; compare the last figure with the 1 or 2% obtained on other alloys of comparable strength. It should not be beyond the wit of modern research to devise means for improving the strength, and more particularly the elastic properties, of this type of alloy without too great a sacrifice in ductility and toughness ; the resulting material would be a notable advance on anything we have at present for castings subjected to really heavy duty.

There has been a considerable increase in the use of aluminium for architectural metalwork in shop fronts, blocks of flats, and public buildings ; aluminium alloy windows, now well-established in America, are also arousing increased interest over here. In some parts of the world such exterior metalwork can safely be left unprotected, but our climate is such that additional protection must be given—for instance, by anodic treatment. The matching of anodic finishes on pure aluminium, wrought alloys, and castings has presented a number of problems. Special qualities of metal have been successfully developed for sheet and sections ; suitable alloys for sand and simple die castings are now also available.

Aluminium Reflectors

An extremely important development, arising out of research into anodic treatments for protective and decorative purposes, has been the recent discovery of special treatments that brighten as well as protect the metal. A two-stage electrolytic treatment for aluminium reflectors was first announced in America, but a rather simpler

method,* giving equally satisfactory results, has been discovered in this country and is being developed commercially. Comparative figures for light reflectivity are as follows :—

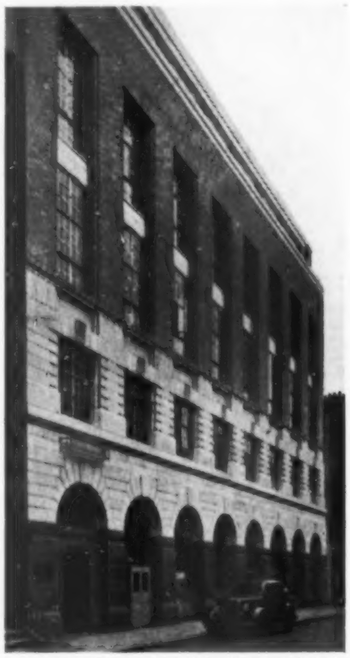
Silvered Glass.	"Brytal."	Nickel-Plate.	Chromium Plate.	Stainless Steel.
100	85	70	68	54

Either specular or diffused reflection is obtainable, the finish is very much more durable than electroplate, and its resistance to heat is such that it can be taken right up to the melting point of the metal before being appreciably affected. Apart from its technical advantages, the new finish should be cheaper than plating, and it is expected that it will almost entirely replace other materials for high-quality metal reflectors.

Aluminium as an Alloying Element

Although not generally thought of as aluminium alloys, the metals in which a small quantity of aluminium plays a vital part are steadily increasing in number and importance.

Non-ferrous matterials now include the aluminium bronzes, aluminium brasses, both non-corrosive and high tensile, precipitation hardened copper-nickel alloys, such as K Monel, magnesium rich alloys, and zinc-base die-casting alloys. Among ferrous materials the nitrogen hardening steels, aluminium irons and steels for high temperature service, and the special magnet steels, are so far the most important, but considerable interest is at present being shown in aluminium additions for other purposes.



Courtesy Architect F. A. Llewellyn, O.B.E.

Fig. 5.—Gerrard Telephone Exchange; windows, spandrels, and exterior metal work in anodised aluminium.

The potency of aluminium as a de-oxidiser has long been recognised, but in this country it has become rather fashionable to decry it as a dope for making bad steel passable rather than good steel better. This point of view is likely to be rendered untenable if recent work on the control of inherent grain size in steel meets with the recognition it deserves, and which, incidentally, it has already received in other parts of the world. Only a minute percentage is required, but its general adoption would increase the consumption of aluminium by hundreds of tons per annum.

It is more than ever important that the aluminium industry should not be content to rest on its laurels, for it is safe to assume that any market successfully exploited by one product is to-day the object of research and development campaigns in favour of one or more others. In addition to established rivals, aluminium is now likely to face increasing competition from plastic materials. It is therefore very satisfactory to be able to record a number of directions where recent developments are enabling aluminium, in its turn, to tap markets hitherto reserved for other materials.

* Known commercially as "Brytal," see *Monthly Journal* of Inst. Met., August 1936.

Progress of the International Nickel Company

THE blowing-in last month of No. 6 and No. 7 reverberatory furnaces at Copper Cliff (Ontario) marked the completion of the first stage of the new expansion programme of the International Nickel Co. of Canada, Ltd. The new 510-ft. smoke stack at the smelter has also been brought into service. The latest work to be begun is the construction of a copper research laboratory costing $400,000, to be erected close to the main office building. The second stage in the programme will be the addition of three new electrolytic units at the Port Colborne (Ontario) nickel refinery, to handle the increased output expected at Copper Cliff. The number of units in operation will then total ten.

With the bringing into operation of the new two reverberatory furnaces already mentioned, together with some of the new converters, an increase of from 15% to 20% in the productive capacity of the Copper Cliff smelter should be effective during this month. Further increases to the estimated limit of 30% will occur in accordance with the growth of the world demand for the company's chief product—nickel. Completion of the programme brings the effective force of reverberatory furnaces up to seven, although only six of these will be in operation at one time. This, however, is believed to be the largest force of effective reverberatory capacity ever assembled under the roof of a single smelting plant. The addition of seven new converters brings the total converter force up to 19. The converter "aisle," together with the adjoining Orford section, has now a total length of more than 2,100 ft., or about two-fifths of a mile. This is believed also to be the largest battery of metal converters under one roof in the world.

At the same time, the company is pushing mine development beyond the highest expectations of officials when development of the Frood mine was undertaken. Originally planned for a daily production of 10,000 tons, the Frood mine is at present providing 11,000 tons of ore per day for the Copper Cliff smelter. Ore for the Coniston blast-furnaces is coming from the Creighton mine, and the total volume of ore undergoing treatment at the company's various plants near Sudbury averages about 13,500 tons daily. With the recent completion of the new No. 5 shaft to a depth of 4,000 ft. at Creighton mine, development has started on six new deep levels, providing for the development of 1,200 ft. vertical depth of this great nickel-copper ore body. By next spring the Creighton mine is expected to be in a position to relieve the Frood of some of its present load, and a production of between 60,000 and 75,000 tons monthly may be raised to more than 100,000 tons monthly.

The new plant brings to the company a measure of flexibility in operation which has never before been achieved in the nickel industry. When the present mine development programme is completed, mining capacity will be somewhat in advance of metallurgical capacity. At the present time, however, the company is unable to speed up nickel production without a corresponding or even greater increase in copper production.

The new plant will also enable the production of copper and nickel to be separated into distinctive channels. The new addition, when operating, will be turned over entirely to the treatment of copper concentrates, whilst four of the old furnaces will be devoted to the smelting of roasted nickel concentrates. The nickel concentrates only are roasted before going to reverberatories.

The rated capacity of the Ontario Refining Co. (now wholly owned by the International Nickel Co.) is 10,000 tons monthly. Last year's production of refined copper was 109,966 tons—almost the rated capacity. With no important additions to the plant, the scale of production during the current year has been substantially increased over that for 1935.

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INDUSTRIAL PROGRESS

EXPANSION in industrial production, which amounted to about 9% and 10% respectively in the first and second quarters of this year, as compared with the corresponding quarters in 1935, continued at the same rate in the third quarter. While there is normally an appreciable reduction in the manufacturing industries, last quarter was nearly equal to that of the second quarter, while the output of coal was greater. The principal increases were in iron and steel, the output of which increased by nearly 20%; non-ferrous metals group, with an increase of about 18%, and the engineering and shipbuilding output by 16%, the latter increase being mainly due to the improvement in shipbuilding and greater activity in electrical engineering. The final figures for the year are not yet available, but despite the crisis through which the nation has passed this month, there is a distinct feeling of confidence that further industrial improvement will be shown when the figures are published.

Generally, it can be said that this year industry has enjoyed steady and continuous progress, and although recent figures give slight increases in the numbers of unemployed, there is no real evidence to justify the belief that the upward trend of employment has yet been checked. Practically all the basic industries are employing more people than a year ago. It is noteworthy, for instance, that engineering, coal-mining, the distributive and cotton trades, are each employing between 20,000 and 30,000 more workers than at this time last year. Even the building industry, which is subject to much fluctuation at this time of the year, is employing over 12,000 additional workmen. Those areas which experienced the greater force of the depression through which the country has passed, are receiving special attention and schemes of development which are completed or have been put in hands—in South Wales, for instance,—together with increased shipbuilding orders in the Clyde and Tyne districts, should assist towards greater prosperity in these areas.

Actually, this country is benefiting from the general upward trend in international trade, of which there were signs early in 1935, and which has moved forward with cumulative force to a more prosperous condition. There is still much in international affairs that gives cause for anxiety to the peaceful development of sane industrial progress, but a nation which can face a crisis with imperturbable demeanour, such as has been shown during the last few critical days, is capable of contributing much to the establishment of world confidence, and it is upon this that industry depends.

Probably one of the most notable features of industrial progress during the year is that concerning the British iron and steel industry. It has passed all previous records of production for steel, reaching a total of approximately 11½ million tons, a monthly average of nearly a million tons. Demand still has an upward tendency, and if the same degree of political and monetary stability is maintained during the coming year, there is every prospect of the present rate of production being at least maintained and probably exceeded. As was mentioned in our last issue, the demand for iron and steel exceeds the capacity of the plants in production, and it was necessary to make adjustments on import duties on certain grades to enable pressing demands to be met from outside sources.

The large output which has been accomplished is a credit to the iron and steel industry. Its executives retained a quiet confidence, even in the most depressing times, and proceeded to reorganise, modify, and equip their works in the sure knowledge that this basic industry would be required to meet a growing demand for steel. That their foresight and energy was not misplaced is indicated by the strong position the industry now holds. The basis of the present prosperity is a wider demand from all steel-consuming industries and the increasing use of steel for a wider range of purposes, due largely to steady progress in research. The shipbuilding, engineering, and building industries are making greater demands, and the development and improvement of alloy steels are enlarging their field of usefulness.

It is gradually being recognised that industrial progress is dependent upon research, which provides a fuller knowledge of the materials available for the use of mankind, and facilitates their development so that they can be applied economically for particular purposes. This is especially true with regard to the less familiar metallic elements, the use of which have been found advantageous for alloying purposes to improve certain properties in the base metal. But in the better-known materials there has been steady progress in their application as a result of improved quality, either resulting from improved technique in manufacture, or from a better knowledge of the properties of the materials employed.

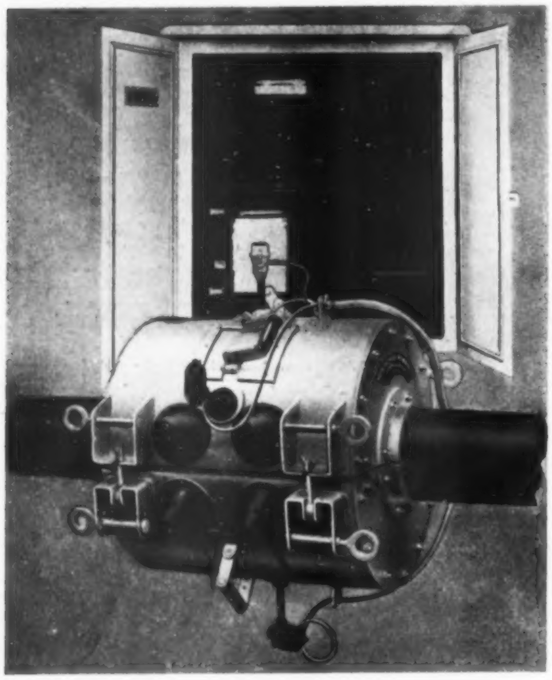
In the production of iron castings, there has been steady progress, notably with regard to graphite in cast iron and its modification; metallurgical coke is receiving attention, and there has been considerable activity shown in the mechanisation of foundries. Refractory materials for use in the foundry have been, and are being, investigated very thoroughly, while the field for alloy-iron casting is broadening. Amongst castings, mention may be made of corrosion-resisting steel castings, which are increasing their scope of usefulness in a wide variety of industries. The value of heat-resisting steel castings is gradually being appreciated—more industries are taking advantage of their attractive properties, and soon they will be regarded as essential for many purposes.

Research work comes slowly to fruition and records of discovery frequently lack the spectacular suddenness and surprise element. This is especially emphasised by the steady progress achieved in the light metal industries. Attention is directed elsewhere in this issue to progress in the use and application of aluminium and its alloys, but not less important are the developments in the manufacture and applications of magnesium and its alloys. The advantages offered by the application of magnesium alloys has been freely recognised by the aircraft industry, and considerable progress has been made in this sphere. In an industry where power-weight ratios have always been of the greatest importance, this attitude was to be expected, but there are indications that similar ideas are spreading to the automobile industry. Further, it should be noted that magnesium and its alloys are being extruded, and bars, tubes, and a variety of sections are available.

The year just closing has been a good one for British industry, and although it has been concerned primarily with manufactures for the home market, the latest figures show a substantial improvement in work for overseas, and it is in this direction that further expansion may be expected in the coming year.

Normalising Welded Pipe Joints

DIFFICULTIES have always been experienced in normalising the welded joints of pipes, especially in those cases where the pipes have been fitted and welded in their ultimate positions, but a recent furnace development indicates that these difficulties can be overcome. This new furnace, designed and built by Metalectric Furnaces, Ltd., of Smethwick, Birmingham, is a portable type electrically heated joint-annealing furnace.



A new electric furnace designed for normalising welded pipe joints.

The furnace, which is shown in the accompanying photograph, is unique in that it is specially designed to heat-treat the joints of pipes already in position, and is constructed for easy transportation from one position to another. It is cylindrical in shape, made in halves, and fitted with suitable locking arrangements, so that the furnace can be clamped around the joints to be heat-treated. Handles are provided for lifting purposes, and loose distance rings are arranged to suit the diameter of the pipe under treatment, so that various sized pipes can be heat-treated. The rings are split to ensure the furnace being concentric to the outside diameter of any sized pipe in a given range.

The furnace is heavily insulated, and to conform with the split rings, different diameter insulating refractories can be used to prevent the entry of cold air and increase in heat losses. The working temperature of the furnace is 600-650° C., and the control of this is effected by instruments housed in a special type portable steel plate case provided with lifting lugs. The heating elements are made of heavily sectioned nickel-chrome strip. In order to attain accurate control, a series of holes is arranged, through which search thermo-couples can be linked to a recorder, so that the actual temperature of the pipe under treatment is recorded throughout the whole treatment period.

Special care in the design and construction of this furnace ensures that it will withstand the rough handling to which it will be subjected in transportation from site to site, and special care has been taken with the arrangement and fitting of the controller and recording instruments, in view of the delicacy of their construction. The design of this furnace opens up a new phase in electric-furnace heat-treatment work, and it is understood that Metalectric Furnaces, Ltd., have under consideration the design of other furnaces of a portable nature for application to a wide range of industries.

Forthcoming Meeting

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Jan. 7. "Powder Metallurgy," by J. C. Chaston, B.Sc., A.R.S.M.

LONDON SECTION.

Jan. 14. "Copper," by R. D. Burn, M.Sc.

NORTH-EAST COAST SECTION.

Dec. 19. "Refractories for Foundry Purposes," by P. B. Robinson, M.Met.

Jan. 11. "Shipyard Metals," by M. A. W. Brown, M.Sc.

SCOTTISH SECTION.

Jan. 11. "Magnesium Alloys," by A. J. Murphy, M.Sc.

SHEFFIELD SECTION.

Jan. 15. "Technical and Industrial Development in the Electrochemical Surface Treatment of Metals," by S. Wernick, Ph.D.

INSTITUTE OF MARINE ENGINEERS.

Jan. 12. "Designing for Economy in Ship Propulsion," by J. F. C. Conn, B.Sc.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Jan. 12. "The Training of Welders," by J. Orr, B.Sc., Ph.D., and W. Heigh.

INSTITUTE OF BRITISH FOUNDRYMEN.

LANCASHIRE BRANCH.

Jan. 9. "Mechanical Aids for Increased Foundry Production," by J. Timbrell.

LONDON BRANCH.

Jan. 6. Consideration of two Technical Sub-Committee Reports :—
I.—"Recommendations of the Non-Ferrous Sub-Committee for Two Leaded Bronzes."
II.—"Dimensional Tolerances for Castings, with Particular Reference to Malleable Cast Iron."

EAST ANGLICAN SECTION.

Jan. 7. "Castings of Non-ferrous Materials," by E. Robson.

MIDDLESBROUGH BRANCH.

Dec. 18. "Plate and Machine Moulding for Repetition Castings," by J. Pell.

Jan. 15. "Making a Diesel Engine Cylinder Liner," by J. C. Charlton.

NEWCASTLE-ON-TYNE BRANCH.

Dec. 19. Joint Meeting with Institute of Metals and Coke-oven Managers' Association.
"Refractories for Foundry Purposes," by P. B. Robinson, M.Met.

SCOTTISH BRANCH.

Jan. 9. "Mechanisation in the Foundry," by N. C. Blythe.

FALKIRK SECTION.

Dec. 21. "Developments in the Production of Ingot Mould Castings," by R. Ballantyne.

SHEFFIELD BRANCH.

Jan. 7. Joint Meeting with the Foundry Trades Technical Society. "Some Foundry Characteristics—Iron, Steel, Brass," by P. Longmuir, D.Met.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Jan. 15. "Some Recorded Water Consumptions and Powers on Merchant Vessels," by T. G. Potts.

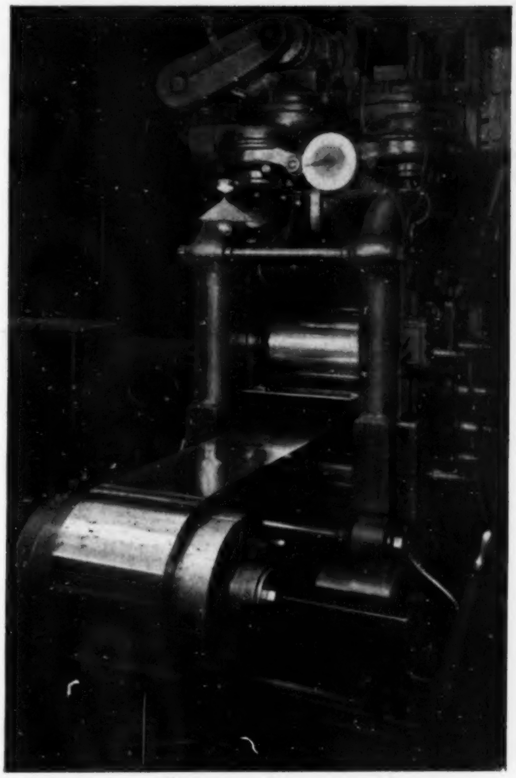
ELECTRO-DEPOSITORS' TECHNICAL SOCIETY.

Jan. 13. "Joint Meeting with Iron and Steel Institute at Northampton Polytechnic Institute, St. John St., E.C. 1. "The Tinning of Steel Strip by Electro-deposition," by D. J. Macnaughton, F.Inst.P., and W. H. Tait.

COLD-ROLLING DEEP-DRAWING STEELS

By J. L. TURNER

Many difficulties are encountered in the production of deep drawing steels, the properties of which are bound up with the details of making, the conditions under which it is hot-rolled, subsequent cold-rolling and heat-treatment, and the reaction of these factors upon deformation, make their manufacture very complex. In this article the author discusses these factors briefly and directs particular attention to the cold-rolling operations.



Cold-rolling strip in a cluster mill at the works of Arthur Lee & Sons, Ltd.

OF the many grades of steel used for pressing into complicated shapes, none presents so much scope and interest as that known as deep-drawing quality, which involves internal rearrangement of the steel under tensile and compressive stress, and the successful use of cold-rolled strip or sheet for this purpose depends upon the intelligent exploitation of its ability to undergo severe plastic deformation without rupture.

Rolling and heat-treating must be carried out within the close limits defined by the final structure and physical properties of the steel, as the latitude in many processes is very narrow. The stress-strain relationship set up in drawing and their relation to those existing in the original mechanical test presents a problem of considerable complexity. The reactions which occur during drawing take place well beyond the yield-point, and often into the necking range. It is, therefore, important that cold-rolled steels should possess the most reliable structure to permit of a wide plastic working range before hardening leads to rupture, and close control of these properties is necessary during the process of manufacture.

The ultimate properties of the steel are bound up with the details of making, the conditions under which it is hot-rolled, subsequent cold-rolling, and heat-treating, and the reaction of all these factors upon the deformation must be taken into consideration. Its manufacture is so complex that experts in various departments of the process have become necessary; each calling for individual study of the problems peculiar to it. It is not possible in an article of this nature to cover all the various branches involved in a comprehensive manner, but there are many aspects of the subject not sufficiently known that can profitably be discussed.

Hot-Rolled Strip

The cold-rolled product is profoundly influenced by the hot-rolling operations, and some reference to the products of hot mills is necessary, together with a description of the process in the order of manufacture through these mills.

One of the chief difficulties encountered in rolling either light or heavy strip lies in getting the material through the mill before it becomes too cold, or in maintaining the temperature uniform at the finishing pass, which is necessary to produce strip uniform in gauge. Usually, the last end of a long strip will be cooled to a temperature so much lower than the first that it will finish several thousandths thicker, unless the mill is adapted to prevent it. These drawbacks are overcome by running the mill at as high a speed as is practicable, and in so arranging and operating it that little time intervenes between passes. Thus, in the modern strip mill, roughing rolls on the universal or continuous plan are used and placed close to the furnace, whence the billet or slab, being reduced in three or four roughing passes, is subsequently taken to the finishing rolls, which may be arranged on the continuous or cross-country plan. Other factors affecting the uniformity of gauge are the wear of the rolls and bearings. Adjustment of the rolls is also important to prevent variation of the section and curved delivery.

It will be seen, therefore, that it is not practicable to produce hot-rolled steel for cold-rolling on simple mills, because the thicknesses desired are small, and it is important to roll long continuous lengths. This means that the work must be done rapidly in order to finish at a high temperature; to facilitate the work, mills must be arranged to save time losses between passes, and to provide the necessary type of roll which will avoid spring and ensure uniform thickness.

Importance of Structure

Apart from these features, the all-important one of structure is of great interest. The changes occurring during the operation of hot-rolling may be considered as equivalent to the simultaneous operations of cold-rolling and annealing, although, of course, the structure consists not of ferrite plus pearlite, but of austenite plus ferrite, according to temperature. The steel in different forms is subjected to deformation over a range of temperatures. Rolling is begun when the slab is in the austenitic condition, and as soon as the austenite grains have been deformed beyond a certain point recrystallisation occurs spontaneously, with a resulting decrease in crystal size. Growth, in the new crystals, continues until sufficient work has again been done to cause recrystallisation and

refinement. The steel gradually becomes cooler and grain growth is slower, also the amount of work necessary to cause recrystallisation is greater, hence refinement occurs at continuously increasing intervals. Thus, from the slab to the strip, grain growth occurs continuously, but at a decreasing rate, while refinement occurs periodically. As the temperature decreases, the refining effect becomes more pronounced than the growth tendency, so that the finest grain size results when the finishing temperature is the lowest at which recrystallisation will occur under the particular conditions. Hot rolling, therefore, is often responsible for considerable heterogeneity of structure, and it follows that the initial structure exerts no influence on the course of recrystallisation after hot rolling.

Grain size and any consequent deterioration in quality is dependent on the pressure and temperature of the last pass, and these conditions reflect themselves in the cold-rolled steel. If the strip is exceptionally long, and there is drag due to the mill pulling up—as frequently happens in older plants—a stage is finally reached when work cannot be put into the steel sufficiently fast to cause recrystallisation under the conditions of rapidly falling temperature, so that the strip leaves the mill with a slightly distorted structure. In some cases, it has been known for this degree of distortion to be equivalent to 10% reduction by cold rolling. To finish above the top range and produce the necessary structure, strip must be rolled on the most advanced type of mill.

Descaling

The first step in cold rolling is the removal of hot-mill scale from the strip, and this is usually accomplished by a combination of mechanical and chemical means. Cleaning plants are of many types, but irrespective of type, the fundamental principles of cleaning are alike. A satisfactory product from this process depends upon the concentration and temperature of the bath, and this in turn should depend upon the quality of the steel being cleaned.

Concentration and temperature cannot profitably be raised beyond certain limits. Excess of these values result in unsatisfactory output. Generally speaking, a bath containing about 20% free acid will be found best, although this solution does not work at the start as quickly as a 15% bath, but, on the other hand, a 15% bath very quickly reaches the point when pickling proceeds at too slow a pace, whereas a 20% bath reaches this point much later. The pickling speed during the entire process is slowly reduced. The main reason for this reduced speed is not so much in the diminution of the acid content as in the increased content of iron sulphate.

The slowing down in speed is compensated for by increasing the temperature. A 20% bath has a commencing temperature of about 50°–60° C., and the temperature will remain constant until the bath concentration is about 10% of free acid. The consumption of acid will vary in different plants, but may be divided in the course of cleaning as follows :—

(*a*) The quantity of acid which is necessary to remove the layer of scale from the steel, calling the pickling-off acid.

(*b*) The quantity of acid which, after the scale has been removed, goes to attack the clean steel, hydrogen being developed at the same time, called the attacking acid.

(*c*) The quantity of acid which on emptying the bath is still in solution and cannot be used, called the end acid.

It should be the aim of every cleaning shop to reduce the figures of attacking and end acids. The end-acid values in a well-conducted plant should not exceed 10% of the acid added to the bath. To reduce the value of attacking acid to the absolute minimum, a restrainer should be added. The consumption of attacking acid is described :—

$$Fe + H_2SO_4 = Fe\,SO_4 + H_2$$

It will be noted that in proportion to the consumption of attacking acid, iron is also dissolved. The proportion is 56 kilogs. of iron to each 98 kilogs. of 100% H_2SO_4, so that any excess consumption of acid means also a considerable waste. To this solution of iron, which is avoidable and which corresponds to the consumption of attacking acid, must be added the unavoidable loss in weight by removing the scale, which may be described as actual pickling loss. Under ordinary working conditions, this loss may vary from $1\frac{1}{2}$–$4\frac{1}{2}$%. These variations are in turn somewhat controlled by galvanic action and the conditions of hot rolling.

Pickle Brittleness

The absence of any restrainer also allows the release of an excessive amount of hydrogen. Immediately the scale is removed and the surface underneath is exposed to the acid, reaction between the acid and the metal takes place, liberating the hydrogen, which partly escapes but also diffuses, from the point of origin, into the steel, where it is probably retained in a state of solution. Owing to the difference in the atomic ratios of iron and hydrogen, even slight quantities by weight cause a perceptible alteration in the properties of the steel. The absorption of hydrogen results in a decrease in the resistance of cracking, decrease in the reduction in area and in elongation, whereas the yield-point and tensile strength remain practically unaltered or may even increase a trifle.

Fig. 1.—Showing the effect of spalling on the roll face.

The extent to which hydrogen is absorbed depends partly on the steel itself and partly on the temperature and concentration of the bath. There is, however, considerable difference, in regard to the absorption of hydrogen between hydrochloric and sulphuric acids. In the former case, the pickling action is, to a major extent, based on the iron oxide being transferred into chlorides ; in the latter case the scale is forcibly removed by the hydrogen.

This absorption not only causes alterations in the steel, but may give rise to the troublesome phenomenon of blistering. Atomic hydrogen passes smoothly and without hindrance through the crystalline network, but any non-metallic inclusions, such as silicates and slag, form an obstacle to its passage ; it then accumulates and forces up the surface in the form of blisters. These blisters usually appear in straight lines, due to the fact that non-metallics are spread lineally by the hot rolling. Experiments made on steels of identical analyses show that the volume of hydrogen absorbed under similar conditions can vary from 2 to 100 c.c.s per sq. ft. of surface. In neutralising the acid, care should be taken not to impair the surface by allowing the iron salts to hydrate and form ferric oxide.

Descaling by a reducing atmosphere derived from coal gas by incomplete combustion (purified to remove moisture and sulphur) and used in a controlled atmosphere electric furnace, is becoming prominent. The oxide is converted to iron, imparting to the steel a silvery white surface which can be cold rolled without any further treatment to produce a high-grade product.

Two High Mills

The cold-rolling mill of to-day is a unit of intricate mechanism requiring driving equipment of many thousands of horse-power and possessing complex auxiliary gear.

Different classes of work call for widely varying treatment in the method of rolling. The modern plant may, therefore, be equipped with two-, three-, four-high or cluster mills, either as single units or arranged on the continuous principle. Apart from type and design, one of the most important parts of a mill is the rolls. In the heavier mills, where strip up to 20 in. wide is rolled, the roughing passes may be accomplished by chilled rolls, but as the tensile and crushing strength increases, chrome alloy rolls are necessary to withstand the high pressures involved in effecting further reductions. Great care is required in the making of these rolls to secure the necessary pearlitic condition, which confers the hardness, toughness, and ductility of heat-treated chrome steel. An average analysis for this type of roll is :—

C.	S.	Ph.	Mn.	Cr.	N.
0·80	Trace	0·025	0·40	1·0 to 2·0	Trace

Increase of the Cr. beyond 2·0% when in the presence of a high carbon content would render the roll useless by inducing a martensitic structure, from which spalling would result in service, as shown in Fig. 1. There is also a danger of these elements being improperly alloyed, resulting in insufficient hardness, in which case the rolls will develop a crazed surface, as shown in Fig. 2.

Fig. 2.—A crazed roll surface due to faulty alloying of the metal.

The internal bore should also be as large as is consistent with safety. In tempering, it permits the heat to be absorbed much more rapidly, and in quenching the heat is more rapidly removed. Furthermore, expansion and contraction strains are largely overcome, and shrinkage cavities in the centre are avoided. The area of greatest segregation lies about the central axis, so that a bore of suitable dimensions should, and does, remove the greater part of all segregated material from the roll. The transverse strength of rounds being proportional to the cubes of their diameters, the central portion is really non-essential so far as strength is concerned. If a 3-in. bore be made in an 8-in. roll, the maximum loss in strength is but 5·25%. However perfect the rolls may be, insufficient and imperfect lubrication of necks or bearings will lead to continual trouble with heating, causing frequent stoppages and, moreover, the resulting variation in the temperature of the barrels renders the finishing of thin gauge strip, within trade limits, almost impossible.

On account of local increase in diameter, due to the generation of excessive heat in the necks, constant readjustment of pressure is necessary. With a breaking-down mill, the load is more intermittent, giving varying periods between passes during which the pressure is removed from the necks. As the breakdown of the rolls may mean a serious stoppage of production, as would be the case in a large mill, it is essential that the bearings are sufficiently robust in construction to render them immune from sudden failure.

Roll Bearings

The plain bearing mill is a most inefficient piece of work, generally only about 40 to 50% of the power applied to the rolls being absorbed by the useful work of reducing the metal, and of the remaining 50 or 60% by far the greater portion is lost in bearing friction. Bearing pressures, which may be anything up to 3,000 lb. per sq. in., could, to some extent, be reduced by increasing the neck diameter and lengthening the bearings, or by using larger rolls than would normally be employed for any given work. Bearings can be kept cool by the application of water, but this is only a partial remedy, and whilst dissipating heat, it does not eliminate the serious loss of power. There is also a danger of sudden breakage owing to rapid uneven expansion and contraction.

Mechanically, the problem is practically solved by the use of roller bearings, which give the highest efficiency and the greatest economy of power, besides eliminating heating troubles. There are, however, unavoidable disadvantages which exist on certain types of roller-bearing mills, and one which is common to all is the heavy concentrated loads which have to be carried by the individual rollers of the bearing. The working life is necessarily limited, and sooner or later these bearings fail, investigation usually proving that breakage is due to fatigue. For light strip mills about eighteen months' continual working is a safe estimation of life.

Efficient lubrication may be effected by high- or low-pressure systems, and the choice is largely dependent upon the type of mill and the work to be done. By maintaining a copious supply of oil to the bearings, extraordinary results in reducing power consumption may be obtained. If an oil film can be maintained between the rubbing surfaces, not only is the wear of the bearing reduced to a minimum, but fluid friction takes the place of solid friction, and even under the heaviest loads the frictional coefficient may be extremely low. By this method soft metals may be used for lining the bearings, and the volume of oil circulated through them may vary from a few drops to 5 gals. per min., according to the pressure used.

(To be continued.)

Metals Resistant to Hydrochloric Acid Solutions

HYDROCHLORIC acid is one of the most active chemicals known, and there are few metals which can be used with safety in contact with it. This is particularly unfortunate, because hydrochloric acid is encountered in many industrial processes. Monel metal and pure nickel are among the materials which have a useful resistance to corrosion by hydrochloric acid. Experience shows that the former is slightly superior to pure nickel, although both are being used. The usefulness of these metals is generally limited to service at atmospheric temperatures in acid of concentration less than about 20%. In hot solutions, the limit is in the neighbourhood of 2%. The lower the degree of aeration and agitation, the lower the rate of corrosion.

Monel metal has been used for a number of years for the metallic parts of equipment handling hydrochloric acid used to wash insecticides from fruits, especially apples. The strength of the solutions is approximately 0·5%, and they operate at a temperature of approximately 110° F.

For the construction of self-supporting tanks handling cold muriatic pickling solutions varying in concentration from 5 to 10% by weight, Monel metal is also employed. Tanks of this kind have been in use for a little over eight years, and present indications are that they will last a much longer time. A longer period of service has been obtained from pickling baskets of this metal in contact with hydrochloric acid solutions : records are available of baskets which have given satisfactory service over a period of fifteen years.

Recent Trends in the Development and Use of Copper Alloys

By A SPECIAL CONTRIBUTOR

In this survey of recent developments which have occurred in connection with copper and copper alloys, attention is focussed mainly upon the applications of these materials in various industries. The author indicates the expanding uses of copper and its alloys and also shows how the development of new alloys has been sponsored by the specific demands of certain industries. Well-established alloys are by far the most important materials from a tonnage point of view, but some of the comparatively new copper alloys offer most interest to metallurgists and technical engineers.

Copper in the Electrical Industry

IN electrical applications copper itself remains as the most important material for conductor purposes, whether in the form of wire of small diameter for instrument purposes or large section bus bars for the transmission of heavy currents. In fact, it is only under somewhat special circumstances that the use of materials other than high conductivity copper is justified.

For applications such as overhead transmission line conductors and trolley wires for traction services, a material possessing both high conductivity and strength, together with resistance to wear, corrosion, and fatigue is required. For such purposes, cadmium copper—an alloy containing 0·5% to 1·0% cadmium, remainder copper, which provides a considerable increase of strength with only a small decrease in conductivity—is being extensively used. As a result, the manufacture of cadmium copper is now being undertaken on a much larger scale than hitherto, and in certain cases the alloy is being produced in bulk at copper refineries, whereas formerly it had only been prepared in small crucible furnaces. Advances have also been made during the past year in the technique of rolling cadmium copper.

Cadmium copper—sometimes containing small additions of silver in order to retard softening at elevated temperatures—is also being applied for welding machine parts. For electrode tips a sintered copper tungsten alloy has been extensively used, while much interest has recently been taken in copper chromium alloys for this purpose.

Silver, in amounts of about 0·05%, considerably retards the softening of copper at elevated temperatures, and alloys containing small amounts of silver have been used for some years in the electrical industry. Corson[1] has recently stated that an alloy containing 3% of silver has been used in U.S.A., which, by suitable cold work and heat-treatment may have a tensile strength approaching 50 tons per sq. in., with a conductivity of the order of 90%. Owing to the high cost of silver, however, the application of such an alloy is likely to be rather limited.

Railway Applications

This field remains one of the most important in connection with the use of copper and its alloys, and during the past year expansion programmes have been undertaken by all the railway companies in this country, while other firms, specialising in the export of equipment to colonial and foreign railways, have also been more fully occupied than for many years past.

The largest single use of copper is in the construction of the locomotive firebox, in connection with which several recent interesting developments have occurred. Tough pitch arsenical copper, containing about 0·4% arsenic has been the conventional British alloy for both firebox plates and stay rods, whereas Continental engineers have generally favoured unalloyed tough pitch copper. The arsenical copper is considered to have the virtues of retaining greater strength under working conditions and of forming a more protective type of oxide scale, although it is realised that it possesses inferior thermal conductivity. Under modern conditions involving higher working pressures and temperatures, more rapid wear of fireboxes has been encountered, with the consequence that repairs and replacements have had to be effected at more frequent intervals.

It is now several years since oxy-acetylene flame welding was tried in Germany for the patching of such worn fireboxes, and this method of repair has been greatly extended, and perhaps to-day can be regarded as standard practice, at least in Continental repair shops. Welding by means of the oxy-acetylene process has also been employed for the actual construction of fireboxes ; stay rods have also been welded in position in the plates with the object of reducing the ring-shaped wastage which occurs around the heads of stay bolts fitted in the conventional manner.

Although success in the welding of tough pitch copper—arsenical or otherwise—can be attained by skilled operators, much more certain results can be achieved with deoxidised copper, and consequently there has within recent years been an increase in the demand for this type of material for both fireboxes and other plant. The most common deoxidant is phosphorus, and this element is usually present to the extent of 0·05% in deoxidised coppers, whether of the arsenical type or otherwise.

The parts of the locomotive firebox which have received most consideration are the side plates and stay rods situated in the highest temperature zone, and which consequently are subjected to maximum distortion, so that leakage and wastage ensue. Much attention has been given to these problems within the last few years, and it is now generally accepted that the materials should be capable of retaining a high limit of proportionality in operation at temperatures up to 350° C. In Germany, it would seem that for side plates the most satisfactory results have been achieved with a mild age-hardening type of alloy, containing nickel and silicon in amounts of about 0·7% and 0·5% respectively, which has in fact been developed from one of Corson's alloys patented over ten years ago. Within the last twelve months, manufacture of this alloy under the trade name "Kuprodur," has been undertaken in this country. A particular feature of the alloy is that it retains high mechanical strength, and shows no tendency to soften after subjection to temperatures considerably higher than are encountered in locomotive firebox service. The successful large-scale use of a temper-hardening or age-hardening alloy for this purpose is extremely interesting, in view of the hitherto limited applications of copper alloys, which exhibit such characteristics. It suggests, therefore, that a wider and greater use might in future be made of such alloys for high-temperature purposes, as indeed will

[1] J. G. Corson. *The Iron Age.* October 22, 1936, p. 29.

be apparent from later remarks made in connection with copper-chromium alloys.

For stay bolts it is again apparent that retention of mechanical properties—and particularly limit of proportionality—at elevated temperatures is essential. Experimental trials have been made with Monel metal, while another development which shows promise and which has only very recently been announced, is that of the copper-covered steel bolt.[2]

Automobile Industries

The automobile and aero industries have experienced within the last few years a continually expanding demand for their products, and this has been reflected in a much-increased consumption of copper and its alloys. For certain components, copper alloys have been replaced by other materials, which permit economies to be made without appreciable sacrifice of performance, as in carburettor and petrol pump bodies, where zinc base alloys, die-cast to more accurate dimensions than are possible with the higher melting point copper alloys, are now almost universally employed. In other directions, however, the use of copper has been expanded, so that perhaps on balance the total requirement of copper or copper alloys per unit has not appreciably changed.

Perhaps the most important recent development from an engineering and metallurgical point of view has been the incorporation of copper in various alloy irons and steels. The Ford Motor Co., of Detroit, has developed a wide range of such irons and steels for various parts of automobiles, and from the recent review[3] which has been drawn up by their research laboratory, it is clear that copper now occupies an important position as an alloying constituent in cast irons and steels, and, as its price is less than that of most other important alloying elements, it is to be expected that wider use will, in future, be made of copper in the production of special irons and steels required by automobile and other industries.

Copper has also been largely used as an alloying constituent in structural steels, and most of the low alloy, high yield strength structural steels, which promise to be of such importance to the transportation industries generally, and which, during the last three years, have been extensively developed in U.S.A., contain copper in amounts of from 0·5% to 1·5%. It is not possible in this short review to consider in detail these fabricated structural steels, but reference might be made to the admirable summaries upon their development which have recently been given by Cone[4] and Gillett.[5] The paper by Epstein, Nead and Halley[6] is also of particular significance in that it analyses in very careful manner the parts played by copper and other elements in modern low alloy structural steels.

With the object of increasing engine power and efficiency, consideration has been given during the last two years or so to the choice of materials for cylinder heads. Aluminium bronze has been used for the heads of certain aero and motor-cycle engines, but the best results, from a performance point of view, accrue from the use of copper heads. As copper possesses almost twice the thermal conductivity of any other practicable material, and about eight times the conductivity of cast iron, the efficiency of copper cylinder heads for removal of heat will be appreciated. Using copper cylinder heads, and with suitable modification to the engine, such as adjustment of the compression ratio, it has been shown that the performance can be improved by 20%. The difficulties of casting copper in the required forms have as yet prevented its commercial adoption, but the Federal Mogul Corporation in U.S.A. has now used copper heads of modified design on a considerable number of petrol engines. In some of these instances chromium has been added to the copper in order to harden and strengthen it without materially affecting the thermal conductivity, a matter which is considered in some detail later.

Marine Applications

The modern tendency to consider more carefully the materials used and their suitability for specific purposes is also apparent in the shipbuilding industry. Consequently alloys of complex composition are being more and more applied, and it would seem that many of the alloys which are now extensively used will tend to become of less importance. In particular, it is considered that aluminium bronzes and silicon bronzes, in both cast and wrought forms, will be more widely applied.

The condenser tube problem was largely solved in this country some years ago, and aluminium brass, of 72% copper, 22% zinc, and 2% aluminium, and cupro-nickel are regarded as the best materials available for the purpose of condenser tubes. In U.S.A., experience with aluminium brass has shown that there is liability of dezincification, and improvements are claimed to have resulted from additions of tin, so that the composition of the alloy has now been modified to 82% copper, 15% zinc, 2% aluminium, and 1% tin.[7]

Materials for Plant Construction

In the construction of copper plant, a notable development has been the adoption of autogenous welding methods, and, as already mentioned in the section dealing with locomotive fireboxes, this has entailed an increased demand for deoxidised copper. A modern development of great interest and potential importance is the electric arc welding of copper, using copper electrodes which are sheathed with special coverings. During welding one of these coatings emits a gas which protects the weld metal while other coatings melt to form fluxes or act as protective sheaths. Matting and Lessel[8] have described such a process; during the past year special electrodes, known as Aerisweld, have also been made available in this country.

During the last few years silicon bronzes have been extensively used in U.S.A. for plant for chemical and related industries. These alloys, containing about 3% of silicon and also additions of about 1% of other elements, such as aluminium, iron, manganese, tin and zinc, have been marketed under the names of Cusiloy, Duronze, Everdur, Herculoy, Olympic bronze and P.M.G. metal. They offer excellent resistance to corrosion, and possess high strength, while it is also possible to fabricate them with comparative ease; amongst other attributes which they possess are good weldability and, in fact, owing to their low thermal conductivity, they can be electrically welded quite as readily as steel. The most widely known silicon bronze is Everdur, and during the last year manufacture of this alloy has been undertaken in this country.

While silicon bronzes are mostly employed in fabricated forms, they may also be used for castings for valves and other purposes. It has recently been suggested[9] that small amounts of cadmium should be added to cast silicon bronzes, as they improve the resistance to the action of steam and incidentally also the casting qualities. Cadmium additions have also been suggested for many other copper alloys.

Other Recent Copper Alloys

Copper Beryllium Alloys.—As representing the strongest of all copper alloys, it is only natural that some reference should be made to the age-hardening beryllium copper alloys, which, although known for about ten years, have during the last year or so received more commercial attention than hitherto. Fabricated alloys containing about 2·25% beryllium are now marketed in U.S.A. at a price of approximately $1 per lb., which is an economic level when contrasted with prices ruling up to a few years ago.

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2 A. Tross. Brit. Patent 444,857.
3 R. H. McCarroll and J. L. McCloud. *Metal Progress.* August, 1936. 33.
4 E. F. Cone. Amer. Soc. Test. Mat. Symposium on High-strength Constructional Metals, 1936.
5 H. W. Gillett. Amer. Inst. Min. Met. Eng.—Metals Technology. October, 1936.
6 S. Epstein, J. H. Nead, and J. W. Halley. Amer. Inst. Min. Met. Eng. Tech. Pub. No. 697, 1936.
7 D. K. Crampton. *Metal Progress.* May, 1936. 39.
8 A. Matting and Lessel. Maschinenbau. Sept., 1936.
9 C. H. Davis and American Brass Co. U.S. Patent, 2,034,563.

The alloys are now being employed in special circumstances, where their high strength and fatigue properties, together with wear- and corrosion-resistance are of particular advantage. One such use is for the landing gear of aeroplanes, while the spring attachment of parachutes provides a further example in the aeronautical field. The largest application of beryllium copper is undoubtedly for non-sparking tools in mining, explosive and related industries, where it is used in cast and fabricated forms on account of its hardness, wear-resistance, and non-sparking qualities. While spring applications form the next most important requirement, the alloy has also been used for bearings, and more recently for dies required in the plastics industry. Comprehensive reviews upon copper-beryllium alloys have recently been given by Stott[10] and Delmonte.[11]

Beryllium copper alloys of compositions most suitable for age or temper-hardening possess much lower electrical conductivity than H.C. copper, and hence some attention has been given to the development of strong heat-treatable alloys which show high conductivity. However, the attainment of superior conductivity is accomplished at the expense of tensile strength. One alloy which has been suggested is Trodaloy No. 1, containing approximately 2·6% cobalt, 0·4% beryllium, remainder copper, which was introduced by the General Electric Co. of U.S.A. in 1935, and patents for which have recently been granted in this country.[12] It is possible to obtain a tensile strength of about 60 tons per sq. in. and a conductivity of over 50% in wire drawn from this alloy.

The high-temperature properties of the binary copper-beryllium alloys are definitely disappointing, as indeed might be deduced from the fact that the temperature required for development of maximum hardness and strength is only of the order of 250–325° C.; at higher temperatures softening ensues. Certain efforts have therefore been directed towards obtaining alloys which would show improved properties at elevated temperatures, as it is widely realised that there are many instances where such characteristics would be beneficial. The aforementioned copper-beryllium-cobalt alloy largely meets the requirements, its heat-treating temperature being of the order of 450–500° C. Among other elements, which have been added to the copper-beryllium series for this purpose, are chromium, nickel, silicon, and titanium. In connection with the latter elements, the work of Comstock[13] is of considerable interest.

Copper-Chromium Alloys.—Increasing interest in this group of alloys has been particularly apparent in U.S.A. within the last two years. The properties of the materials have been generally known for some years, but they have not been commercially exploited until quite recently; this has mainly been on account of the difficulty of controlling the composition. When containing chromium in amounts of approximately 0·2% to 1%, the alloys exhibit temper-hardening characteristics, but the most important feature is that in the tempered condition they show exceptionally high electrical and thermal conductivity. For example, an alloy containing 0·5% of chromium possesses, in the softened condition, mechanical properties slightly superior to those of copper, and the conductivity is about 40%; when tempered at 550° C. or thereabouts, the strength is approximately doubled, and the conductivity is raised to 85%. The alloys lend themselves readily to fabrication by hot and cold working processes, and they may be obtained in the form of strip, sheet, rod, and wire.

A further important advantage of the alloys is that they retain their strength at moderately high temperatures and consequently they have been applied for purposes which call for such properties. One particular application for which they have been extensively used in U.S.A. is for the tips of welding electrodes.

10 L. L. Stott. Amer. Inst. Min. Met. Eng. Tech. Pub. No. 738, 1936.
11 J. Delmonte. *Metals and Alloys.* 1936. 7, 211, and 239.
12 British Thomson Houston Co., Ltd. Brit. Patent 448,400.
13 G. F. Comstock. *Metals and Alloys.* 1936, 7, 257.

Improvements in the properties of the straight copper-chromium alloys are claimed to result from additions of cadmium, silver and zinc, and a series of patents covering such alloys has been issued in America.

Other Chromium Alloys.—Particular reference might be made to bronzes containing chromium additions, as it would seem that these are destined to become of considerable importance for bearings and similar applications. The range of the copper-tin alloys which can be hot-worked is also increased by the presence of chromium, presumably due to the latter exercising an influence upon the distribution or constitution of the delta phase in the castings. Alloys which may be worked hot range in composition from 3% to 10% tin, 0·5% to 10% chromium, 0·2% to 4% iron or cobalt, and 0·2% to 1% vanadium.[14] In the normal way, only bronzes containing less than about 3% of tin may be hot-worked, so that this advancement opens up quite a new field, and offers prospects for the wider use of bronzes.

Alloys with Selenium.—The addition of selenium to copper-base alloys, particularly of the cupro-nickel type, has been suggested,[15] with the object of improving machining properties, but so far such alloys do not appear to have been commercially exploited.

The Relationship between Mechanical Tests of Materials and Their Suitability for Specific Working Conditions

The paper on the above subject, given by Dr. N. P. Inglis, at a meeting of the North-East Coast Institution of Engineers and Shipbuilders, opens with a discussion of the various requirements usually embodied in a purchasing specification for an important steel forging. Each of the clauses usually included is critically analysed in the light of the information which the required tests give to the designer and user. Certain clauses, the inclusion of which in a specification is sometimes the subject of some controversy, are specially considered and justification for their inclusion is given. It is shown that, in general, the information obtained from specification tests indicates to the purchaser the general quality of the article, and is necessary to ensure that the quality conforms to a normal standard. The specification tests in themselves do not ensure suitability for a particular set of working conditions. Further information, derived from special tests or from previous experience, is necessary in conjunction with the specification tests.

The examination of parts that have failed in service is dealt with, and also the deterioration of mechanical properties under certain service conditions. Two particular cases of the deterioration of notched-bar impact values as a result of service are considered very fully.

In the first case, the deterioration of the notched-bar impact value of certain alloy steels after prolonged service at 350–450° C. is considered. An attempt is made to determine the precise practical significance of the reduced notched-bar impact value. Results are given of various types of tests on the same steel in its original condition and in its condition after service in the above temperature range.

In the second case the deterioration of the notched-bar impact value of mild steel at sub-normal temperatures is discussed. Certain test results, on the effect of heat-treatment and cold work on the low-temperature notched-bar value, are given. Again, an attempt is made to assess the suitability for service of material that has a low notched-bar impact value, but has excellent properties in other respects.

14 M. G. Corson and J. Stone, Ltd. Brit. Patent 445,620.
15 C. S. Smith and American Brass Co. U.S. Patents 2,038,136 and 2,038,137,

Progress in Seamless Tube Manufacture

BY GILBERT EVANS

The development of revolutionary methods of tube production has led to great progress in the tube industry. With new processes technique has been developed and the manufacture of tubes from stainless irons and steels and also heat-resisting steels is now firmly established, while the extruding process is able to deal in bulk with such compositions as Monel metal, Duralumin, cupro-nickel, pure nickel, etc. In this article the manufacture of seamless tubes is briefly reviewed, and attention directed to the factors which have contributed to its progress.

Large continuous Pilger mill for the production of seamless steel tubes at the Mannesmann Tube Works, Rath.

PERIODICAL stocktaking of progress, improved methods, new inventions, and the like, are inevitable in most trades, and the necessity of being alive to developments is an essential requirement of the consultant whose operations include duty visits to foreign countries. Where keen competition has to be encountered, the first question with which he is greeted is, what is the latest method of production ? Have there been any revolutionary methods introduced in our special line of manufacture ? This experience is common to all consultants whatever the particular branch of trade in which they operate. In the writer's own particular branch of tube manufacture, it is recognised that any extension or addition to plant results in advice being sought in Germany, Great Britain, and America, and the countries named are arranged in sequence of being the pioneers in the tube trade. It may be profitable, in support of this assertion, to review briefly the earlier developments in the tube industry.

The first invention of the rotary type of piercing mill was operated in Komatau, Remscheid, and Düsseldorf, by Mannesmann, in 1885, which was brought to Landore, South Wales, Great Britain, in 1888. Stiefel's machine of the disc type was evolved at Landore and taken to America, where it was developed in 1895. Ehrardt's process was patented originally in 1891, it being installed in Great Britain some years later. Similarly, the Pilger or step-by-step process for extending or rolling hollow steel blooms emanated from the Mannesmanns in Germany in 1891, and in a short time was installed and developed in their Landore works. All these inventions were revolutionary methods of tube production, and at the present time they maintain the position held at the date of their inception, as with the expiration of patent rights they were universally adopted, some in modified form, throughout the trade in all countries.

In the Mannesmann or Stiefel types of mills, the steel billet at a temperature of 1,400–1,450° C. is subjected to extreme torsional stresses set up between the rolls and/or discs with varying circumferential speeds, while being forced over a mandrel or piercing head. At an early stage in the Mannesmann type of mill, a claim was made that the process produced the only tube with the spiral fibre, a claim which was quickly abandoned when the effect of the piercing operation on the material was scientifically investigated.

Revolutionary is not a term to be applied to modifications and/or improved efficiency. The introduction of the seamless tube process in its early development was heralded as likely to revolutionise the butt- and lap-welded tube trade, which is, however, in a flourishing state to-day, perhaps especially so in the smaller sizes and in its application to the requirements of water, gas (low pressure), and steam.

In more recent developments it is difficult to name processes likely to revolutionise any particular branch of tube-making, but the choice would be between the inventions of Peter Alfred Foren and the White cold reducing process, with the Diescher elongator a good runner-up. All these have been developed in the United States in quite recent years, and all have been installed and operated in Great Britain and on the Continent. The Diescher process and principle has been extensively reviewed,[1] the principle of which is shown in the accompanying illustration. The Foren mill has also been described.[2]

The most revolutionary process, the White reducing machine, applies specifically to the cold-drawing of tubes, and with the increased excellence of tubes of hot-finished quality in the steel branch, by which the demand for cold-finished is perceptibly decreased, its arrival or development may be said to be somewhat belated. Of its utility there is no question, especially in its relation to non-ferrous tube manufacture, in which it is applied to material which is ductile in its cold state. The action of this reducing mill is in principle similar to the Pilger mill, which, however, operates on hot metal. The wear and tear of the Pilger mill is generally recognised as fairly excessive, so in the application of the white mill to steel in its cold state, special steel mandrels and changeable roll sections may be needed to ensure its commercial success.

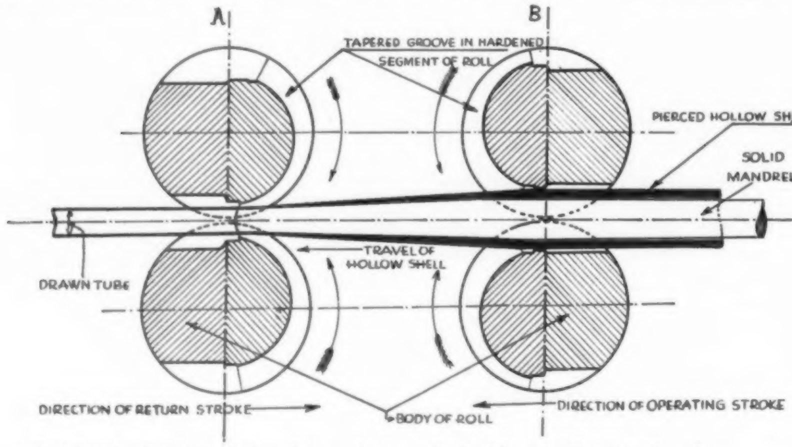
Its application to the non-ferrous branch of tube manufacture is successfully demonstrated in a large tube works in Sweden, but so far as actual results are concerned, it is questionable whether this type of plant will completely replace the oldest universal machine in use in all factories—viz., the endless chain draw-bench. As a result of waviness left on the surface of the tube made by the process under review, it has been found necessary to give one, or at times two, cold passes to the tube to obtain the high smooth finish demanded by most specifications. Further reference will be made to the White reducing mill.

It was not without misgiving as inventor of a successful piercing machine in universal use in the non-ferrous trade that one realised that, by the introduction of the extruding press, a very definite competitor had to be considered. This introduction was hailed as likely to cause a revolution in the non-ferrous trade. Where the smaller diameters were concerned the results obtained were definitely successful, but where large diameters and long lengths were required the limitations of extruding were evident, so both processes still operate side by side.

In the contributory stages of tube manufacture there are ample avenues for investigation by the scientific and

1 Gilbert Evans, METALLURGIA, vol. 9, No. 52, pp. 117–120.
2 Gilbert Evans, METALLURGIA, vol. 12, No. 67, pp. 27–28.

technical minds, one of which is the abolition of annealing and pickling between the draw passes, and in stating this, the writer is not ignoring the great strides made by the introduction of bright annealing with its freedom from oxide. In the earliest days of the trade, a poor imitation was achieved by sealing the finished article in pots, made as far as possible air-tight by means of fire-clay joints. In view of the difficulties in dealing with large production, many were the methods adopted to impart the close annealed finish, including the application of black lead.



A *Position of rolls at completion of operation at the point the tube is partly rotated.* B *Position of rolls at starting of operation.*

Method of cold-drawing and reducing tubes. White's process.

Diverting for a while to material qualities or analyses, here is a field in which marked advances and improvements are apparent. On the ferrous side the manufacture of tubes from heat-resisting and austenitic steel, as well as from stainless iron, is now firmly established, the initial process being confined in the main to the extrusion press. The writer was fortunate in being present at the first demonstration of the extrusion of stainless steel, which at that time was shelved on account of the unsuitable quality of the mandrel and dies. Now, however, its manipulation is taken as part of the ordinary day's work. Similarly, in the non-ferrous section, with its ever-increasing demand for excellence in quality and finish, the extruding process is able to deal in bulk with mixtures such as Monel metal, Duralumin, cupro nickel, pure nickel, etc., and in line with the application of these metals and alloys came the demand for dies and plugs for use in the cold-draw finishing process.

The draw-bench's value to the tube trade is as unassailable to-day as when first applied to the welded iron trade by Cornelius Whitehouse, of Wednesbury, in 1825. The speed in drawing has a definite effect on the various alloys, and in most modern plants benches with variable speeds are installed direct driven by variable-speed motors. The value of variable speed had been demonstrated in a practical manner in the old-fashioned type of bench, in which two separate gear ratios were employed, the use of either being dependent on a jaw-clutch sliding on a feather in the shaft. The pair of gears which were not in use for certain speeds were generally lined in the bore with a brass bush in which the driving shaft revolved. They were cumbrous machines compared with to-day's benches, but not in any way less effective.

In existing times the question of speed is maintained by the use of dies and plugs of a quality and cost undreamed of in the pioneers' day. The call for finish like a mirror has been met by the introduction of even chromium-plated plugs and dies, tools which represent considerable initial outlay.

As has been indicated, the question of annealing has formed a subject of deep study by technical staffs, and use of the electric furnace has been a great factor in improving one of the principal phases in tube manufacture. No up-to-date concern would to-day tolerate open annealing, with its inevitable marring of good work. A modern annealing furnace of the type referred to may have an over-all length of over 200 ft., including, as it does, charging and discharging stands, with continuous feed, and, where necessary, quenching arrangements. The first demonstration of this type of furnace viewed by the writer was at the works of Henry Wiggins, Ltd., which at that time created a furor in both the ferrous and non-ferrous tube trade.

In reverting to the White tube-reducing process and its possibilities, in view of the general opinion in the tube trade since its inception, it is necessary to emphasise that the amounts of reduction of wall thickness and diameter were definitely limited, and the White process has promise of being actually revolutionary in this respect. The reductions in sectional area of material in the cold state are amazing, and while the installation outlay is costly it is balanced to some extent by the elimination of expensive items of manufacture, such as pickling and annealing, and further by the fact that two or more machines can be governed by one operator.

Its similarity to the Pilger, or step-by-step process, in universal use in the manufacture of hot-finished tube, is further emphasised by the fact that in 1894, under patent 6283, Benjamin Price (who was a Mannesmann employee) claimed in his specification an apparatus for making tubes from hollow ingots on the step-by-step process, in which the operating swages or rolls are given a reciprocating movement in the direction of the length of the ingot, and at the same time are caused to approach one another on each side of the ingot. In 1900 O. Heer, of Düsseldorf, under specification 14416, claimed that the housings of gapped rolls are swung on a horizontal axis, thus reducing shock when work is inserted. These two inventions were definitely the first introduction of reciprocating roll movement as applied to the manufacture of tubes.

In the cold-drawing operation, one of the recognised factors is that the amount of reduction of the internal diameter is limited, a factor which is applicable to the white reducing machine. To submit either ferrous or non-ferrous metal to too much " sink " results in a breaking up of the internal surface. As a rule, it is sufficient to allow a difference between the bore of the tube and the mandrel governing the diameter in the following process, for the tube to slip easily over the mandrel. An allowance of $\frac{1}{8}$ in. minimum is observed in the application of the White process. A further similarity is noted in the roll or swage design, when compared with the Pilger mill, in that it is not necessary to change the roll body in its entirety for varying diameters.

In the writer's early days with the Mannesmann Co., attempts were made to introduce segments into one universal roll body for various sizes; these were secured by various designs of circular taper wedges, but owing to the expansion of the roll body and segments the idea was shelved for good. Such conditions are not applicable when operating on cold material. Whereas in the Pilger hot process a parallel mandrel is used, the tool used in White's mill is definitely tapered; the rolls in the former completely revolve; in the latter, with its reciprocative action, the rolls traverse by means of a sliding saddle, and do not completely revolve. The inserted segments have grooves similar to the Pilger mill, as will be noted in the accompanying illustration, the bottom of both top and bottom grooves being eccentric to the axes of the respective rolls, and in each process, tube and mandrel are submitted to partial rotation to eliminate the rolling of flats or fins on the section of material under operation.

The writer has superintended the manufacture of tubes up to 40 ft. long in Pilger mills, and by the new cold-drawing or swaging process one definite advantage over the somewhat limited length of tube in the endless chain bench is that longer hollow shells can be used, resulting in much longer finished tubes. It will be realised that in a reciprocating application of power the surface of the finished article is subject to a certain amount of waviness, hence the need for treatment through a die and over a mandrel to produce highly finished exterior and interior surfaces. It is revolutionary to find that, with suitable material, an average reduction of 70 to 80% can be effected with no detrimental effects on the grain or structure of the metal.

A matter of interest to those interested in ferrous and non-ferrous tubes is that such has been the improvement in steel quality that it is possible, in converting the solid billets into hollow blooms by the rotary piercing process, that the same setting of the main rolls and piercing plugs are applicable to either metals, a development which even in recent years would have been scoffed at by the ferrous trade. This, reduced to a more illustrative form, means that it is now possible to pierce (as example) a 3-in. solid steel billet of suitable quality and at a temperature of 1,350° C., over a piercing plug $2\frac{3}{4}$ in. to $2\frac{7}{8}$ in. diameter, producing a hollow bloom approximately 3 in. dia. × $\frac{3}{8}$ in. or $\frac{7}{16}$ in. wall thickness, as compared with former practice of piercing over $1\frac{7}{8}$ in. piercing plug and expanding at same heat over a $2\frac{1}{8}$ in. plug.

Verein Deutscher Eisenhüttenleute

Annual Meeting in Düsseldorf

Discussion at this meeting was primarily devoted to practical questions, such as heat economy in production and heat-resistance materials. Several paperswere presented, summaries of which are given in this article

IT will be remembered that the last annual meeting was devoted entirely to the celebration of the 75th anniversary of the Verein deutscher Eisenhüttenleute and to the inauguration of the new Institute building for iron research. On the occasion of the recent meeting practical questions were the primary consideration, and owing to the large number of members present, it was necessary to transfer one of the sessions from the Institute to the Tonhalle. The more important questions discussed are summarised in the following :—

Problems of Heat Economy

A joint meeting of the Heat Economy and Rolling Mill Committees was held to deal with the further development of present-day heat economy in the operation of rolling-mill furnaces. In contrast with previous years, when the saving of fuel was one of the chief problems of heat economy, the idea of improving the quality of the fuels has recently come more and more into the foreground. The steel-making furnace has come to be regarded as an instrument which, by its operation, strongly influences the quality of the finished rolled product and thus also the economy of steel production. The furnace is, in fact, a point of contact for the heat engineer and the rolling-mill expert. For this reason three papers dealt with the influence of heating and annealing furnaces on the surface constitution of the material and its temperature, and on the possibility of counteracting undesired effects of the furnace-gas atmosphere on the surface of the heated material.

Dr. Ing. habil. W. Heiligenstaedt discussed the scaling of steel, due to heating with coke-oven gas, and gave results of tests on the influence of differently adjusted combustion ratios, temperatures and heating periods in the case of various types of steel, and the degree of scaling of the material. He regarded scaling as a diffusion process, in which a reciprocal diffusion takes place between the oxygen-containing constituents of the combustion gases and the pure iron in the surface of the heated material, while there is a simultaneous formation of the scale layer. The rate of diffusion depends on the heating period, and on the temperature and thickness of the scale layer which is formed. In view of the fact that an exact knowledge of the laws which are operative in the process makes possible a comparatively simple calculation of the quantities of scale produced in each heating process, the further investigation of the diffusion process during scaling is of considerable practical importance.

The importance of depth heating for the construction and operation of gravity discharge furnaces was discussed by Dr. Ing. F. Wesemann, who considered the depth heating as the difference of temperature in the cross-section of the heated material which arises in every heating process, and which, if excessive, may have a very adverse effect on the rolling-mill products, rolling breakdowns, and the energy consumption during the rolling. For this reason the preliminary calculation of the depth heating, on the basis of heating process in the gravity discharge furnace, in which the material is moved towards increasingly heated combustion gases was the aim of a number of scientific investigations, the results of which have been tested and confirmed more recently. According to these investigations, the depth heating depends on the thickness, the chemical composition, and the heating period of the material. By means of the adjustment of the heat supply, and more especially by heating the material, not only, as is usual, from above, but also from below, the depth heating may be considerably improved.

For this reason the so-called " bottom heating," which is at present only applied in a very limited number of cases, deserves the special attention of furnace constructors, although its intensification involves numerous practical difficulties. On the other hand, the relation between the above-mentioned influences and depth heating will result in very important new knowledge concerning the optimum efficiency of heating furnaces and their characteristics for this purpose. Further details are elucidated by the temperature differences arising between the ingot surface and the scale layer, while the aggregate state of the furnace residue, which comprises the given-off scale, is determined by the temperature, the rate of heating, the thickness of the material being heated, and finally the estimation of the temperature of the heated material.

The adjustment or artificial production of an atmosphere favourable to the material treated in a heat-treatment furnace has rapidly gained in importance, partly owing to the increased demand made on the material, and partly owing to the introduction of new types of materials and new processes. The obvious difficulties of this many-sided problem were reviewed by Oberingenieur G. Neumann, who stated that in many cases an elucidation will only be possible on the basis of special tests. The possibility of providing a favourable natural combustion-gas atmosphere in the furnace with a directly fuel-heated heat-treatment chamber was considered in detail, and the speaker indicated the conditions which were necessary for the provision of a favourable atmosphere in muffle and electric furnaces *without* introducing protective or reaction gas from the outside. Finally, different processes were

described, some already in use and some still in the course of development, for the production (outside the furnace) and introduction into the heat-treatment chamber of protective or reaction gas of arbitrary composition.

The number of furnaces operating with a protective gas atmosphere in the steel-making and steel-processing industries probably already exceeds a thousand. Plants for the production of protective gas for these purposes are already supplied in series with nominal outputs of up to 500 m.^{3}/h. Plants for the production of similar reaction gases with several times this capacity are already in use in the chemical and ceramic industries.

Heat-resisting Steels

The agenda at the second session embraced papers and discussions principally on steels possessing high heat-resistance, which could be regarded as cheaper than those in general use. The first paper dealing with this problem was by Dr. Ing. Fritz Brühl, on the structure and properties of chromium-manganese steels with varying chromium, manganese, and carbon contents. By means of killing tests, the author determined that manganese does not extend the austenite range at low carbon contents. On the contrary, the ratios of the iron-chromium-carbon system determine the austenite formation. Manganese only lowers the critical rate of cooling, and ensures that the austenite, which, once formed, maintains itself even in the case of long-time annealing. For this purpose, manganese contents of more than 5% are necessary. According to the carbon content, the structure of killed alloys consists of: α solid solution, $\alpha + \gamma$ solid solution, or γ solid solution with different carbide contents. In the case of alloys containing more than 10% manganese, which, when tempered subsequent to the killing, form a stable austenite, it was ascertained that, when an $\alpha + \gamma$ solid solution structure is present after the killing, the α solid solution decomposes into FeCr plus austenite. It appeared, furthermore, that alloys with 30% of chromium, when tempered, also decomposed into FeCr. Both the measure and the rate of the transformation are independent of the carbon, manganese, and chromium contents. An increase in the manganese content advances the formation of the FeCr solid solution An increase in the carbon content reduces the formation of the FeCr solid solution. The optimum temperature for the transformation is approximately 700° C. The formation of FeCr was proved by means of X-rays, metallographically, and by means of hardness and saturation measurements.

By means of investigations of the mechanical properties, the influence of killing and tempering was tested for various steel alloys. Here also the appearance of the combination could be observed without difficulty. Welding tests on alloys, which could be used in practice, showed that the weldability is fairly good. The resistance to corrosion is lower than that of the usual non-corroding chromium-nickel steels. It was tested in nitric acid, acetic acid, and sulphuric acid. The corrosion resistance was also tested in water-vapour-air mixture. The resistance to scaling is also lower than in the case of the present-day heat-resisting alloys.

Further investigations on heat-resisting chromium-manganese steels were discussed in a paper by M. Schmidt and H. Legat. In order to determine the most favourable alloying range of chromium-manganese steel for heat-resisting structural purposes, the authors of this paper have investigated steels containing less than 0·20% of carbon with a manganese content up to 35%, and a chromium content of up to 30%. The mechanical testing of the steels included the determining of the Brinell hardness and the notch toughness at room temperature subsequent to annealing at temperatures up to 850° C., and further tensile tests at temperatures of up to 900° C. The range of stability and the phases present in this structure in the iron corner of the iron-chromium-manganese equilibrium diagram was determined from the structure of the steels after killing in water from 1,100° and annealing of 700°. The optimum steel compositions for heat-resisting steels were determined by means of scaling tests at temperatures of up to 950°.

As regards the applicability of chromium-manganese steels, the authors have come to the conclusion that chromium-manganese steels can only replace the heat-resisting chromium-nickel steels within a specific temperature range, as they cannot be made scale-resisting much above 900° C., owing to the limitation of the permissible chromium content. They can, however, be readily used up to this limiting temperature, and deserve greater consideration than has formerly been the case, in view of their good workability, heat-resistance, toughness, and their resistance to sulphur.

A topical problem, which is being considered extensively owing to the wide application the science of welding has obtained during recent years, was discussed by Dr. Ing. F. Bollenrath, Berlin, in his paper on the reduction of inherent stresses in welded containers as a consequence of operation.

Tests were made on the weld stresses in the case of two test drums of boiler-plate, one of which had been made by the electric arc welding process and the other by gas-fusion welding. After a critical consideration of the usual methods for the investigation of inherent stresses, the drilling method and the measurement of radial displacement in the vicinity of a drilled hole in relation to the depth of drilling was chosen as the most expedient. This method is in accordance with the one advocated by J. Mathar.

The welding stresses were determined in the as-supplied condition, and subsequent to a three-stage pressing with pressures of up to 42 atm. In this connection the total deformation under a load of water and the additional stresses caused by pressing were observed. The decrease of the weld stresses were thereby determined in detail.

In the case of the test drum produced by the electric arc welding process, and which had not been subjected to any subsequent treatment, the maximum stresses approximated the yield-point of the material in the seam and were low in comparison to the other weld stresses measured in level plates. The stresses were decreased by the equivalent of the additional stresses as the result of each added load—*i.e.*, the total stress in no case exceeds the initial inherent stress. The weld stresses therefore do not in the slightest reduce the load capacity of the drum, so long as the weld is perfect, and so long as small plastic deformations are possible in the weld connections. In the case under review, the quality of the weld was perfect. No defects appeared even in the welding seams which were drilled several times and again sealed with threaded bolts, although the drum was subjected to stresses, by means of an excess interior pressure, which approached the yield-point of the boiler material. The reduction in stress was very considerable, and averaged 55%.

In the case of the test drum produced by the gas-fusion welding process, the weld stresses were lowered considerably as a result of a far-reaching sub-division of the weld seam into individually welded sections, and as a consequence of a planned subsequent treatment—*i.e.*, annealing, forging, annealing, so that they did not exceed the yield-point of the boiler material. In this case also no defects appeared in the welds when similarly pressed under a maximum of 42 atm. The weld stresses were considerably reduced, and in parts completely eliminated, although not so uniformly as in the case of the electrically welded boiler. The height of the inherent stresses is, however, so low that it may be regarded as unimportant for the reliability during operations, the reasons for which are mentioned above.

We have received a large 1937 calendar from the Carborundum Co., Ltd., Trafford Park, Manchester, 17. The characteristic Indian head which is so familiar is probably more impressive than on previous occasions, and the colouring is remarkably effective. We understand that a few copies of these calendars are available for distribution, but early application is advisable.

Mechanical Properties of Single and Multiple Aluminium Crystals

By G. WELTER and T. MOJMIR
(Department of Metallurgy, Warsaw Polytechnic)

The influence of the grain of aluminium on the change of micro-mechanical properties—namely, on the limit of elasticity—modulus of elasticity and micro-deformation has been studied. It has been ascertained that the purity of the material has a definite influence upon the shape and orientation formed by the recrystallation of the grain, thereby influencing the resisting properties—i.e., the limits of the grain perpendicular to the axis of the test-bar (for material containing 99·8% Al) decrease the resistance and increase the elongation, but the limits of the grain parallel to the axis of the bar (in the case of a material containing 99·5% Al) increase the resistance at the expense of the elongation, whilst in the multiple crystal tests the smallest elongation takes place at the limits of the crystals. For single crystals it is possible to observe a definite transition from elastic to plastic deformation. With the increase of the diameter of the grain the value of the resistance of the material is decreased; further, the influence gets stronger at first and then becomes much more uniform.

SYSTEMATIC investigations regarding metallic crystals go back over a period of barely 15 years, and have been the first steps in the development of one of the youngest branches of metallurgy. The properties of metallic objects are defined by two factors: by the characteristic properties of the single crystal, and by the additional changes caused by the aggregation of the crystals. In order to develop the science of metals, modern investigations into their resistance properties have been directed along the line of tests covering the resistance feature of single crystals.

The generally known property of crystals is the anisotropy of their mechanical properties, the so-called variable behaviour under the influence of external forces, depending upon the orientation of the crystals with regard to the axis of the test or to the direction of the forces applying —*e.g.*, tensile.

The results of the tests made with respect to the anisotropy of aluminium monocrystals are best explained by the radiovectors of the mechanical properties, such as resistance and elongation, plotted according to the directions of Czechralski by Göler and Sachs.[1] These experiments show that the resistance of an aluminium crystal is of greater magnitude in the direction of the angle axis than in the direction of the main axi (approximate ratio 1 : 2). The radiovector of elongation shows that, according to the crystallographic direction, it varies in the ratio of 1 : 3·5). The difference in value of the modulus of elasticity in the direction of the axes is not very great, and amounts to about 20%.

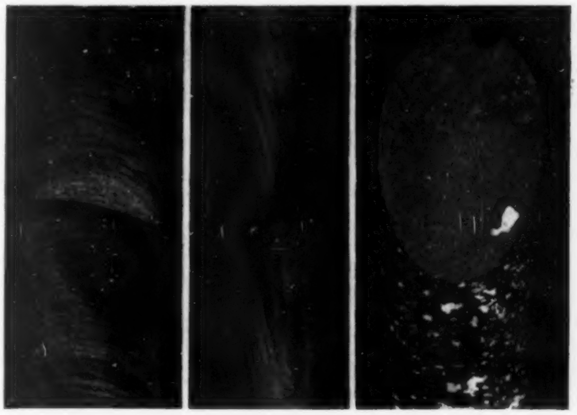
In order to define the mechanism of deformation of metals, it is necessary, first of all, to consider their crystalline structure. A single crystal is not actually deformed in the same direction as it is stretched. The work of such research workers as Taylor, Carpenter, Sachs, and Schmidt, has shown that at the time of deformation of a single crystal the following will occur :—

(1) A shift along crystallographic planes in certain selected directions.

(2) A rotation of crystalline planes, thus forming " twin " crystals.

The deformation of a single crystal of aluminium when stretched takes place by a sliding over the plane and by a change in direction. As an example of double sliding of an aluminium crystal which was fractured during the investigation, the illustration (Fig. 1) will serve. It will be noticed here that the lines of translation traverse at an angle of 45 degrees.

The mechanical properties—viz., resistance, elongation, and hardness—of single aluminium crystals have already been investigated and described among those of other metals. Other mechanical properties, however, such as the yield-point, micro-deformation and limit of elasticity as function of the direction of the crystal axis, have not as yet been thoroughly investigated.



a b
Fig. 1.—Showing the fracture of an aluminium crystal. *Fig. 2.—Recrystallisation after repeated heating.*

Preparation of the Material for Examination

This work has been undertaken with a view to ascertaining these remaining properties of single crystals. A few sets of aluminium bars of 10–12 mm. in diameter and 100 mm. and 70 mm. in measured length were prepared by recrystallising. Two qualities of aluminium were used—viz., (1) 99·8% Al and (2) 99·5% Al.

A great number of bars of each quality were required, because only 20% of the total number of tests produce, in recrystallising, single crystals of suitable size for investigating micro-deformation, and not all the crystals thus obtained have a suitable orientation for studying their anisotropy.

The resistance tests were divided into macro-deformation and micro-deformation tests. After recrystallisation the bars were turned down to a thickness of 8 mm. in diameter. The pressure exerted during the turning and polishing of the test-bars caused surface tension ; after repeated heating it was possible to prove recrystallisation on the surface in the form of small crystals, such as is shown in Fig. 2. A single crystal is clearly seen here in the centre, deformed on its outside surface and covered with small crystals.

[1] Göler and G. Sachs. Z. techn. Phys. 8, 586 (1927).

Fig. 3.—Arrangement of crystals in aluminium of 99·5% purity.

Macro Tests

Recrystallisation of the two grades of aluminium has shown a great difference in orientation of the crystal limits which naturally had a considerable influence on the deformation during the tensile process. Fig. 3 represents a characteristic arrangement of the limits of aluminium crystals of 99·5% purity. As will be seen in the illustration, the material shows the grain limits parallel to the axis of the test-bar, while aluminium of 99·8% purity has the crystal limits perpendicular to the test-bar axis, as shown in Fig. 4.

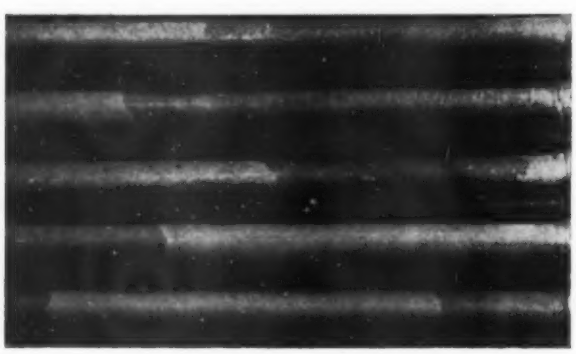
In order to prove this, the tests with aluminium of 99·8% Al purity were repeated twice, and material of different origin was used. The results were identical in both cases. Generally said that during stretching the limits of the crystals parallel to the axis of the test-bar (Al 99·5%) have a resisting effect upon the sliding orientation, thus causing the decrease in elongation and consequently increasing the resistance. The limits perpendicular to the axis of the test-bar in the case of 99·8% Al, causing an aggregation in the vicinity of the limits of the crystals of the resistance test-bar, thus preventing the formation of an elliptical cross-section, which takes place only at some distance from the limits of the crystals (see Fig. 5).

In case of multicrystalline material, with crystal limits perpendicular to the axis of the test-bar, the crystal limits show a greater resistance and less elongation than the actual crystal itself. Experiments on the lines of the tests made by Yamaguchi[2] have shown that the elongation of a test-bar consisting of two crystals is lowest at the limits (Fig. 6). The first crystal (on the left) was ruptured at the point of maximum elongation.

The elongation of the first crystal in close proximity to the left of the contraction point amounted to 5·6 mm./cm., the corresponding elongation of the second crystal being approximately 4·5 mm./cm., whereas the elongation near the limit crystals was only approximately 2·4 mm./cm. For the sake of comparison, elongation curves of a polycrystal (dotted line) are also shown.

2 Yamaguchi. Sci. Pap. Inst. phys. chem. Ref. Tokyo, 11 Nr. 205, 223 (1929).

Fig. 4.—Arrangement of crystals in aluminium of 99·8% purity.



For general orientation purposes, a series of tests on mono- and poly-crystals under load have been made to study the plastic deformation close ro breaking point.

Fig. 7 represents mainly the state of aluminium mono-crystals during stretching. The cross-section of the test-bar (originally circular) flattens out during stretching and becomes elliptical. In the illustration can be observed the characteristic contraction of the bar in the form of a socket, at first slightly darkened (*a*), and then steadily more deeply (*b*). The last stage before the breaking point shown by the bottom photo (*c*). A typical fracture of a mono-crystal (side view) is shown enlarged (approximately 5 in. diameter) by the illustration (*a*) shown at Fig. 8. The same fracture seen from above magnified, approximately 8 in. diameter, is shown in (*b*), Fig. 8, where a typical socket-like break is to be seen. This is the normal fracture of the test-bar of a single aluminium crystal.

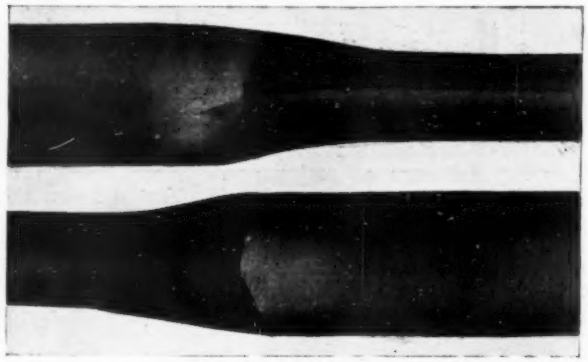


Fig. 5.—Effect on the limits of the crystals on the surface of the resistance test bar of 99·8% Al.

Fig. 9 shows a comparison between different kinds of test fractures, formed by several large crystals or mono- and poly-crystallising bars. Test-piece (*a*) consists of four crystals, having their axis limits parallel to the axis of the test bars. The shapes of the circular test-pieces were changed under the influence of the breaking strain into a cross-section resembling a rectangle, as will be clearly seen from the cross-section perpendicular to the axis of the bar. Test-piece (*b*) presents the normal elliptical fracture of a mono-crystal, whereas test-piece (*c*) shows the fracture of a circular cross-section of a poly-crystalline bar.

The existence of different fractures of Al crystals is further proved by the fact that a fracture can be obtained of the large crystallic test-piece, passing partly through the crystal limits: this is shown by Fig. 10. The interesting result of the break may be explained by the opinion that, apart from over-heating, the test-bar has been several times under load up to the limit of plastic deformation, and that only after a certain period (approximately three weeks) it was broken down.

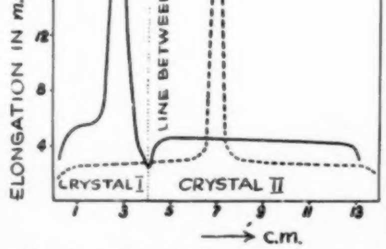
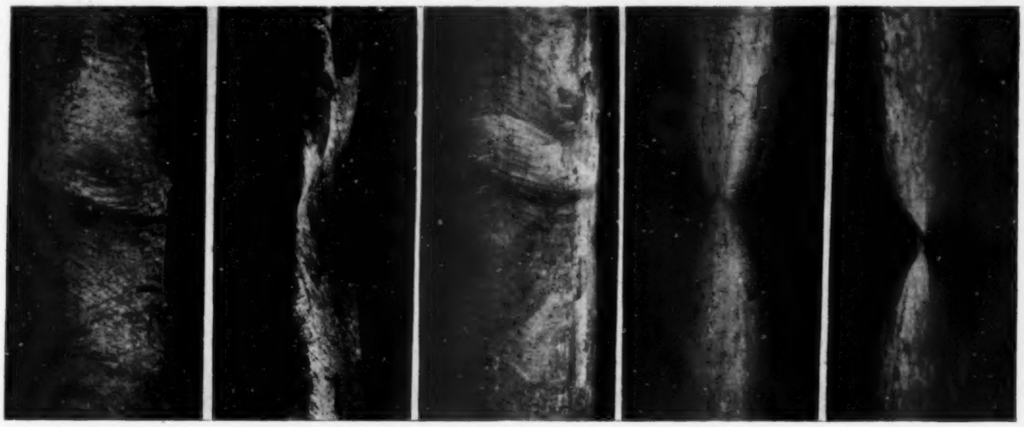


Fig. 6.—Curve of elongation of general parts of aluminium test-piece comprising two crystals.

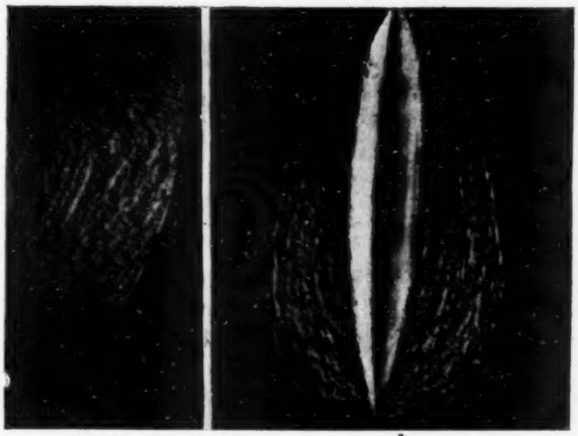
Micro-Tests

The micro-deformation tests carried out with the aid of Martens' apparatus, were aimed at ascertaining the limits



a a b b c

Fig. 7.—Showing the condition of aluminium monocrystals during stretching.



a b

Fig. 8.—A typical fracture of a monocrystal (a) enlarged about 5 dias. (b) enlarged about 8 dias.

of elasticity at 0·001% and 0·01% of permanent deformation, the limit of plasticity at permanent deformation 0·2% and the Young modulus E.

The resistance tests of mono-crystallic Al of 99·8% purity have shown big differences in the values of the modulus of elasticity E, or limits of elastic deformation, as shown in the graph Fig. 11.

This graph shows that the tensile strength in kg./sq. mm. depends upon the microplastic and elastic deformation of Al crystals in different crystallographic directions. The maximum value of modulus E was 6,450 kg./sq. mm. (curve 6), whereas the minimum was 5,250 kg./mm.^{2} (curve 7). The maximum value of modulus E measured during the series tests was near to the minimum value mentioned in literature (Table I, Nos. 1 and 3). The tests, having 7–10 crystals over a measured distance (4), have shown a maximum value of modulus as E–6,000 to 6,500 kg./sq. mm., according to the purity of the metal. For an industrial poly-crystalline material (6) modulus E amounts to 7,500–7,700 kg./sq. mm.

The limit of elasticity at 0·001% of permanent deformation for single crystals in the first series lies (1) between the value 0·9 and 1·6 kg./sq. mm.—*i.e.*, approximately halfway between the minimum and maximum values. In the second set of tests (2) the figures were a little less—viz., 0·75–1·36 kg./sq. mm.

According to Czochralski's[3] figures, the limit of elasticity of a single crystal of Al lies between 0·5 and 1·2 kg./sq. mm. and also shows approximately 50% anisotropy. The discrepancy between the results obtained in this work and those mentioned above might be explained by the difference in the state of purity of the materials which, it is known, must have a considerable influence, apart from anything else, upon the elastic and microplastic properties of the metal.

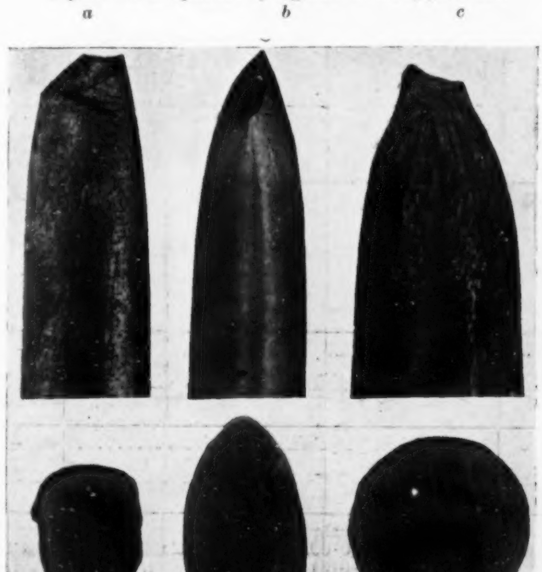
A characteristic feature of all micro-deformation curves of single crystals is, as shown in Fig. 11, a distinct transition from elastic to plastic deformation, although it is impossible to ascertain a relation between this phenomenon and the direction of the crystal axis. For micro-elongation of 0·01% permanent deformation, the discrepancies between corresponding tensile stresses lie between 1·35 and 2·1 kg./sq. mm. for the first series (Table I), and between 1·03 and 1·49 kg./sq. mm. for the second set (2)—*i.e.*, again, approximately 50%. The same will be observed for the yield-point at 0·2% permanent deformation, the values for which, calculated for the second series (2), are from 1·3 to 1·95 kg./sq. mm.

To establish a relation between the tensile strain at the elastic limit of deformation of 0·001% and the direction of the test-bar axis has not yet been possible. For this purpose a great number of micro-deformation tests is necessary. For the first series test (Al 99·8%) the investigation on micro-deformation have shown a certain relation between the actual resistance (*i.e.*, relation between load and actual cross-section) and modulus E, as illustrated in curves 3 and 7 (Fig. 11), as represented by Table II.

It will be noticed that for a maximum modulus of 6,450 kg./sq. mm. we have a maximum actual resistance

Fig. 9.—A comparison of different kinds of fractures.

a b c



3 J. Czochralski, "Moderne Metallkunde," 250, Berlin (1924).

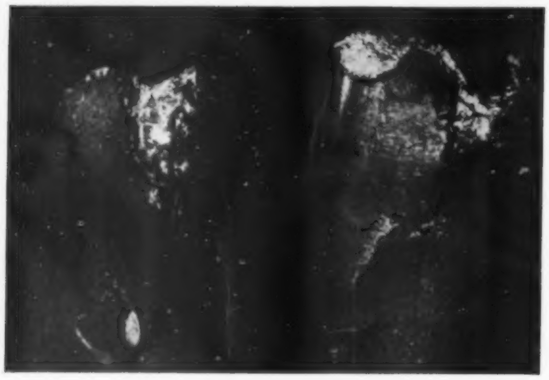


Fig. 10.—Another type of fracture on a large crystallic test-piece.

of 8·1 kg./sq. mm. of a single crystal, and for a minimum modulus of 5,250 kg./sq. mm. the minimum value of actual resistance will be 5·6 kg./sq. mm.

The investigations into micro- and macro-deformation have shown in general and lower resistance of test-pieces, consisting of several crystals, compared with the resistance of mono-crystallic tests. The explanation of this occurrence is, that in tests comprising several crystals the crystal nearer to the direction of least resistance was ruptured. Consequently, the resistance properties of these tests lies between the maximum and minimum results for single crystals, but approach the minimum results. Fig. 12 shows the curves for single crystal load/elongation (macro) tests of the first series (99·8% Al), from which is distinctly seen the influence of the orientation of the crystal upon the elongation and resistance of the material. For the first series (Table I. 1), the elongation varies, according to the orientation of the crystal, between 97 and 54%, and the resistance between 3·93 and 4·84 kg./sq. mm. Tests of the second series (Table I. 2) have shown an elongation from 96 to 53·2%, and a resistance also very similar to the resistance of the material in the first set.

The resistance figures given by Karnop and Sachs,[4] on the basis of which the radiovectors have been constructed, are distinctly higher than those obtained in this work—*e.g.*, resistance 5·9–11·5 kg./sq. mm.). Elongation figures, according to Karnop and Sachs, are 19–68%, compared with values of 54–97% in this work. From these comparisons it is seen that the figures given in the previous study show an anisotropy of approximately 100% for breaking strength, whereas the anisotropy, according to the results of this work (Table I., Nos. 1 and 2), comes to approximately 25%, which tallies equally with the figures given for E.

TABLE II.
THE RESISTANCE PROPERTIES OF ALUMINIUM.
TESTS OF 99.8 % Al. (1st SERIES.)

No. of Test.	Rr. kg./mm.²	Ref. kg./mm.²	0·002 kg./mm.²	A %	C %	E kg./mm.²
1	4·04	6·15	1·7	37·6	34·4	5,500
2	4·03	6·8	1·48	67·2	41·0	6,300
3	4·34	8·1	1·52	68·0	46·5	6,450
4	4·15	5·83	1·5	38·5	28.7	6,100
5	4·38	6·21	1·5	40·5	30·9	5,500
6	4·06	7·28	1·54	62·3	44·3	6,000
7	3·98	5·6	1·34	59·0	29·0	5,250
8	4·18	7·77	1·32	68·5	46·1	5,800
9	3·93	7·16	1·12	66·1	45·2	5,600
10	4·84	6·48	1·26	57·0	25·4	6,000
11	4·48	6·51	—	59·0	34·5	—

Rr = Tensile resistance.
Ref. = Actual value of breaking strain.
0·002 = Limit of elasticity for permanent elongation, 0·002%.
A = Elongation.
C = Yield.
E = Modulus of elasticity.

The elongation values obtained in this work also do not agree with those of Karnop and Sachs. The large discrepancies between the resistance values, according to Karnop and Sachs and the authors of this work might partly be explained by different degrees of the purity of the materials.

[4] R. Karnop and G. Sachs. Z. Phys. 41, 116 (1927).

TABLE I.
MECHANICAL PROPERTIES OF ALUMINIUM.
TEST PIECES OF VARIOUS GRAIN AND DIFFERENT STRUCTURE.

Test No.	Material.		0·001 kg./mm.²	0·01 kg./mm.²	0·2 kg./mm.²	Rr kg./mm.²	Ref. kg./mm.²	A %	E kg./mm.²
1	Single crystals prepared for this investigation, 1st series, 99·8% Al.		0·9 to 1·6	1·35 to 2·1	—	3·93 to 4·84	5·6 to 8·1	97 to 54	525 to 6,450
2	Single crystals prepared for this investigation 2nd series, 99·8% Al.		0·75 to 1·36	1·03 to 1·49	1·3 to 1·95	3·94 to 4·94	—	96 to 53·2	5620 to 7150
3	Single crystals: data from earlier investigations		0·6 to 1·2	—	—	5·9 to 11·5*	—	68 to 19†	6,400 to 7,700†
4	Test pieces comprising several crystals	Al. 99·8%	—	—	—	3·7 to 4·7	—	68 to 32	Max. 6,000
		99·5%	—	—	—	6 to 7·1	—	17·8 to 53·5	5,300 to 6,300
5	Polycrystallic test-pieces	Al. 99·8	—	—	—	6·58	—	38	—
		99·5	—	—	—	8·26	—	31·5	7,200
6	Industrial polycrystalline test-pieces		—	—	5 to 8	7 to 12	—	45 to 30	7,500 to 7,700

* According to Czochralski. † According to Sachs.
0·000 = limit of elasticity for permanent elongation .... 0·001%
0·01 = „ „ „ „ „ „ .... 0·01%
0·2 = limit of yield „ „ „ .... 0·2%
Rr = tensile resistance. Ref = actual value of breaking strain.
A = elongation. E = modulus of elasticity.

The Tensile Resistance and the size of the Grain of Poly-Crystalline Test-pieces

The function of tensile resistance to the diameter of grain for poly-crystalline tests is shown by the curve in Fig. 13. Here it is seen that for small grain of a diameter of less than 0·1 mm. the resistance of the material comes to 6·8–6 kg./sq. mm., and by increasing the grain size it decreases at first rather sharply and then more gradually to a figure of 6 kg./sq. mm. for a diameter of approximately 2·3 mm. the breaking strength reaches a value of 5·8 kg./sq. mm. It will be noted that the resistance varies within the limits investigated by approximately 25% of the lower value. The material of larger grain does not show intercomparable results, since the anisotropy of the test-pieces are more and more distinct.

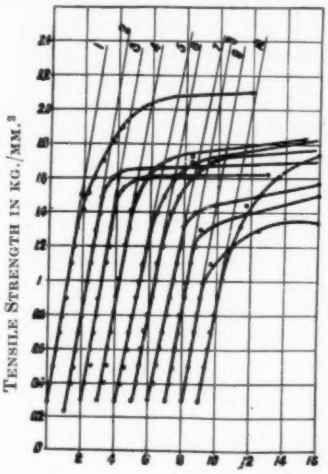


Fig. 11.—*Curve of micro-deformation of single crystals of aluminium in different directions.*

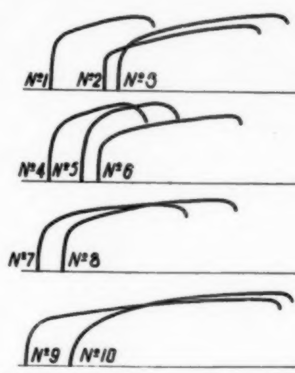


Fig. 12.—*These curves represent load/elongation (macro) for single crystal tests of the first series* (99·8% Al.).

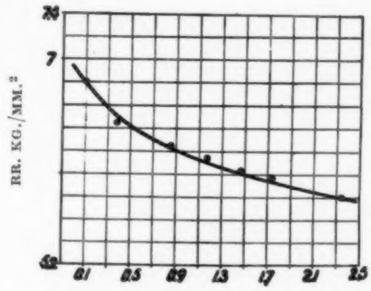


Fig. 13.—*The function of tensile resistance (Rr) to diameter of grain (d) for poly-crystalline tests* (99·8% Al).

Summary

As a result of this investigation, the authors draw the following conclusions :—

(1) The shape and direction of the grain, obtained by recrystallisation, depends upon the purity of the material. For instance, material of purity 99·8% Al produces grain with limits perpendicular to the axis of the test-pieces, whereas material of a purity of 99·5% Al will produce grain with limits parallel to the axis.

(2) The direction of the limits of the grain of poly-crystalline test-pieces has an influence upon the resistance of the material—viz., the limits parallel to the axis increase the resistance at the expense of elongation, whereas perpendicular ones decrease the resistance and increase the elongation. In addition, the direction of the limits has a decided influence upon the shape of the test-piece when breaking.

(3) The conclusion drawn by Yamaguchi, that the minimum elongation appears on the crystal limits, has been proved to be correct.

(4) For mono-crystals a sharp transition from elastic to plastic (Fig. 11) deformation has been established; the value of the limit of elasticity, according upon the direction of the axis of the test-piece, thus varies from 0·75 to 1·6 kg./sq. mm., and the value of modulus E between 5,250 and 7,150 kg./sq. mm. The actual resistance varies from 5·6 to 8·1 kg./sq. mm., whereas the resistance calculated on the original cross-section does not show any distinct discrepancy. The elongation of mono-crystals varies between 53·2 and 97%.

(5) In poly-crystalline material the resistance decreases with an increase in the diameter of the grain, at first fairly sharply, and subsequently more gradually. Within grain limits of 0·1 to 2·3 mm. the decrease amounts from 6·7 to 5·8 kg./sq. mm.

Engineering Alloys: Names, Properties, Uses

The authors of this important reference book have adequately described the scope of their work in the preface, and I can do no better than to quote their own words "The authors of the book have made a careful compilation of the available data and information on practically all proprietary, commercial and technical alloys manufactured in the United States of America, and on many alloys made in foreign countries, including England, France, Germany and Sweden. The book is devoted to data on the chemical composition, physical and mechanical properties, uses, and manufacturers of proprietary alloys." The book is divided into seven sections, as follows :—

(1) Alphabetical list of alloys with index number.
(2) Trade name, composition, properties, uses, general remarks and a key number designating the manufacturer and the reference for each alloy as listed in serial order.
(3) Index of alloys classified according to typicl uses or special characteristics such as corrosion resistance.
(4) Alphabetical list of manufacturers with a summary of the alloys listed that are produced by each.
(5) Manufacturers with addresses in serial order according to the key number.
(6) References in serial order according to their key number.
(7) Appendix containing useful tables and miscellaneous information.

Section two, the most important part, lists its information where available, under the following headings :—serial number, alloy, manufacturer's number, reference number, composition, treatment, tensile strength, yield point, percentage elongation, percentage reduction of area, Brinell Hardness number, uses, remarks.

The book established itself at once as the standard reference book on its subject, superseding previous lists like the Louis Cassier Company's "Metals and Alloys," Campbell's "List of Alloys" and the list in volume two of the "International Critical Tables."

Not all standard specifications are included and no critical analysis of the data given has been undertaken. Checked by one list which was not available to the authors when they compiled the work, that of aluminium alloys in Grützner and Apel's supplementary volume to Gmelins "Handbuch der anorganischen Chemie," several omissions are revealed. This was inevitable as the authors indicate. Nevertheless this is far and away the best list so far.

By Norman E. Woldman and Albert J. Dornblatt, published by the American Society for Metals, 7016, Euclid Avenue, Cleveland, Ohio. Price $10.

Sintering Plant at Staveley's Devonshire Works

The new plant at Staveley has a sintering area of 430 sq. ft., and the rate of travel of the pallets varies between 20 in. and 54 in. per min. according to conditions. The plant is briefly described.

THE latest principles in sintering for the blast-furnace are illustrated by the "Dwight-Lloyd" plant at the Devonshire works of the Staveley Coal and Iron Co., Ltd., which has a capacity of 700 tons of sintered material delivered per 24 hours, treating all the fines below ⅜ in. from the iron ore crushing plant. Chiefly Northamptonshire, Leicestershire, and Frodingham ores are used, partly calcined, while there is added to the smalls all the flue dust, pyrites, spent oxides, and other available fine iron-containing material.

The mixed product is passed to a large main hopper at the feed end of the machine, and a second hopper is included for the hearth layer. Both of these hoppers have roller-feed mechanism, so arranged that the pallets are first covered with about 1½ in. of the hearth layer, followed by the material to be sintered in a layer about 7 in. to 10 in. deep, as already mentioned. Ignition takes place under a coke-oven gas-fired muffle, and the sintered product discharges from the other end of the machine to an inclined chute and over an inclined static grizzly, where it is sprayed

General view of sintering plant at the Devonshire Works of the Staveley Coal and Iron Co., Ltd.

Feeder tables under the sinter bunkers of the "Dwight Lloyd" sintering plant at the Devonshire Works.

with water. Here any fines below ⅞ in. are separated, followed by passage over a vibrating screen, the product below ⅜ in. being returned to the rotary mixer and the over-size delivered to the hearth layer conveyer belt, being mixed with ½–1¼ in. iron ore. The graded sinter, after separation of the fines, is taken by an automatic skip hoist conveyer to a super-elevated bunker, for supply to the blast-furnace by means of transfer cars.

The main sintering plant is contained in a separate steel frame brick building, and for the whole plant, including accessories, 31 electric motors, totalling 827 h.p., are installed, while the power consumption is about 15 kw.-h. per ton of sintered material, and the operating costs less than 2s. per ton.

The "Dwight-Lloyd" machine, manufactured by Messrs. Huntington, Heberlein and Co., Ltd., consists essentially of a long, horizontal, endless travelling chain of metal carriages or pallets, having a flat door formed of firebars on which is deposited a layer about 7 in. to 10 in. thick of the material to be sintered, mixed with coke breeze, and containing the correct proportion of moisture.

At Staveley the over-all length of the machine is 93 ft., and the pallets are 6 ft. 6 in. wide, the total sintering area being 430 sq. ft., and the chain is driven by means of a 25 h.p. variable-speed motor with reduction gearing, the rate of travel varying between 20 in. and 54 in. per min. Under the pallet track are 11 wind-boxes, each with butterfly valve control, all connecting by steel trunking to a sinter fan, driven by direct-coupled slip-ring variable speed motor of 675 h.p., which pulls air for combustion down through the pallets and discharges the waste gases to two brick-lined dust collectors.

The installation includes eight large storage bunkers, five of which, of 190 tons capacity each, are for the iron ore smalls, and two, of the same capacity, for the other material and for a hearth layer, while the eighth takes the coke breeze, holding 106 tons. All these bunkers discharge to separate adjustable-speedfeeder tables, which in turn pass the contents to a main belt conveyer discharging to a large horizontal rotary mixer, provided with internal baffle-plates. By this means any desired proportion of the iron ore smalls and other products are mixed thoroughly with coke breeze, which as a rule is 7 to 10% of the total weight, but may be less if the flue dust contains much unburnt carbon.

The deposits of iron ore in the U.S.S.R. are estimated at 10,612 million tons, of which 8,000 million tons are prospected deposits. The U.S.S.R. occupies first world place in respect of iron ore resources. Within the boundaries of the Union are three-fourths of the world supply of manganese. The U.S.S.R. has deposits of copper, lead, zinc, tin, and nickel running into millions of tons. In respect of gold production, it is claimed this country now occupies second world place. Further, there have been discovered rich deposits of mercury, wolfram, molybdenum, magnesium, urane-radium ores, arsenic, bismuth, antimony, beryllium, tantalum, cobalt, and other rare metals, while the deposits of bauxites are estimated at 21,650,000 tons.

Reviews of Current Literature

The Future of Canadian Mining

SOME idea of a number of changing aspects in the economic life is given in this book by the Hon. T. A. Crerar, Minister of Mines in the Canadian Government, which contains a series of twelve radio addresses given by him on the mining industry of Canada and its meaning to the Dominion. During the first decade of this century, the agricultural settlement of the East and West exerted a profound influence on the general development of the Dominion. It resulted in the remarkable growth of Canada as a wheat-producing country, and provided a prosperous basic industry. Unfortunately, the long period of economic stress throughout the world and the growth of economic nationalism have operated against the further development of this industry. Happily, however, Canada is a country exceptionally endowed with broad territories where not only have metals been found to occur, but where their concentration is in such richness that they can be produced more cheaply than in most competing countries.

The extension of Canada's metal industries has been the outstanding development in recent years in her economic situation, and the progress has not been alone in physical development, but has included important improvements in metallurgical practice. Canada is enjoying a state of industrial recovery, and her condition is largely due to the revival in demand for those products she is able to supply from her great natural resources. Probably the most outstanding feature is the remarkable expansion of her gold-mining industry. The higher price for the metal has improved the outlook for large deposits of low-grade ore, which are assured of successful operation. Further, the presence of gold in association with base metals has aided the production of the latter and has enabled some of Canada's base-metal producers to continue their operations with much more favourable results than would have been possible otherwise. At the turn of the century, Canada was a base-metal importing country ; to-day she has become a great metal exporting country. About 1921 her exports of lead and zinc began to be important and to have greater value than the imports of these metals. In copper, exports have exceeded imports from early in the century, but only since the building of electrolytic refineries in 1930 and 1931 have imports of that metal dwindled to a trifling amount. In nickel the exports have always dominated the imports, and at present about 99% of Canada's production is exported.

All interested in the mining industry will find this book of interest, particularly those who have watched the rapid growth of the mining industry in Canada during comparatively recent years. The information is presented in a lucid manner, yet it is full of interest, and it gives a very vivid conception of the extent, variety, and value of the Canadian mining industry.

It is understood that single copies of this volume may be obtained free of charge from the Director, Bureau of Economic Geology, Department of Mines, Ottawa, Canada ; or from the Secretary, Office of the High Commissioner for Canada, Canada House, Trafalgar Square, London, S.W. 1.

Metal Castings

This book is concerned primarily with the materials and processes employed in the production of metal castings, so that the title is somewhat misleading. It is prepared as a textbook designed to facilitate the organised study of materials and processes, and the author has been careful to explain the reasons for the selection of materials and the procedure used in the manufacturing processes. Comparatively little space is allocated to actual moulding practice, the major part dealing with melting processes for cast iron, methods and equipment for cleaning or reclaiming castings, the constitution of cast iron, the classification of iron castings, calculation of the metal charges for the cupola, malleable iron castings, steel castings, non-ferrous metal castings, the design of metal castings, and the comparative properties of the cast metals.

There is much valuable information of a fundamental character in this book, which will be particularly useful to the student, and it is presented in such a lucid manner that will assist him in grasping its essential significance ; on the other hand, the chapter dealing with metal charges for the cupola contains very useful guidance for those who hold executive positions in the iron foundry. The accurate proportioning of the metals used in cupola charges is one of the most important factors contributing to the economical production of iron castings, especially when alloy metals are involved in the composition desired, and a proper knowledge of the methods by which reasonable accuracy of the metal mixtures can be assured, is essential to competency.

A useful part is the Appendix, which occupies about 36 pages. Here is given much tabulated data suitable for reference purposes ; specifications for cast metals ; methods for sand-testing ; and methods for core-testing. The information given is of a comprehensive character, and the book is well illustrated. A bibliography is appended to each chapter to aid those who desire further information on the subjects presented.

By Harry L. Campbell, M.S. ; published by John Wiley and Sons, Inc., New York, U.S.A. and Chapman and Hall, Ltd., Covent Garden, London, W.C. 2 ; price 15s. net.

The Scientific and Technical Factors of Production of Gold and Silverwork

This book, which contains a series of lectures given at Goldsmiths' Hall, in the winter season of 1935-36, reviews from a scientific and technical point of view the principles of production of gold and silver articles. The lectures represent a new departure, since in recent years the lectures organised by the Goldsmiths' Company have always dealt with the historical and artistic aspects of the craft. In the last series special attention is given to the possible application of the modern scientific knowledge of metals, with the object of assisting progress in the gold and silver trades.

In an introduction to this series of lectures, Dr. R. S. Hutton reminds us that the post-war years have been exceptionally prolific in the scientific study of metals, and other trades have revived themselves by making use of the results. The microscope, the pyrometer, electric furnaces, and X-rays have all contributed to our more intimate knowledge of the properties of metals, and thus to our powers of controlling them and improving both working processes and the final product ; the knowledge thus obtained can be applied to the service of the gold and silver industry.

The series of lectures published in this volume comprise "The Metallurgy of the Alloys of Gold and Silver," by Mr. Donald McDonald ; "Working the Metals," which incorporates rolling sheet and the manipulation of sheet in hand-raising, spinning, stamping, and pressing operations, by Dr. R. S. Hutton ; "Annealing and Heat-treatment," which deals with the processes and results of heat-treatment, both for softening and for hardening alloys, and the prevention of oxidation, by Mr. W. A. C. Newman ; "Jointing and Soldering," by Mr. H. A. P. Littledale, which discusses a new process of hard soldering and its possible connection with the methods used by the ancient Greeks and Etruscans; "Polishing," by Dr. R. S. Hutton, dealing with methods and results of finishing processes ; and "Plating," by Mr. S. Field, in which the processes of plating and colouring in relation to the gold and silver trades are discussed.

This volume will be read with more than ordinary interest by those engaged in the gold and silver trades, because the methods of manufacture and the several processes which are employed in the casting, working, annealing and polishing call for frequent examination and overhaul, and the information it contains will assist their scientific study.

We understand that a limited number of copies are available at 1s. each, on application to the Clerk to the Goldsmiths' Company, Goldsmiths' Hall, London, E.C. 2.

Symposium of High-Strength Constructional Metals

This symposium comprises five extensive technical papers and discussion presented at the 1936 A.S.T.M. regional meeting. The papers cover the chemical and physical properties, manufacturing and fabricating properties of metals and alloys applied for various constructional applications, including buildings, ships, motor-vehicle bodies, aeroplane wings, tanks, etc. The latest information and data are given in these papers on carbon and low-alloy steels, corrosion-resisting steels, alloys of copper, alloys of nickel, and alloys of aluminium and magnesium.

The low-alloy high-tensile steels discussed include nickel steels, medium manganese steels, silicon structural steels, chromium-vanadium steels, manganese-vanadium steels, carbon-molybdenum steels, and manganese-molybdenum steels. The high chromium and high chromium-nickel alloys are discussed in an informative manner under the heading of corrosion-resisting steels. The alloys of copper considered include the heat-hardenable alloys, copper-nickel-aluminium, copper-nickel-tin, copper-nickel-silicon, copper - beryllium, copper - beryllium - nickel, copper - beryllium-cobalt, and copper-chromium. The principal high-nickel materials of construction considered under the heading "Alloys of Nickel," are covered by three compositions: Pure nickel, Monel metal, and an alloy of nickel and chromium. A wide range of aluminium and magnesium alloys is also discussed, and with its many charts and tables of data this symposium presents a fund of valuable information in a condensed form.

The symposium deals primarily with high-strength constructional materials, a subject which has widespread and increasing interest because of the large number of relatively new alloys which have been developed.

Copies of the publication of 126 pages can be obtained from A.S.T.M. Headquarters, 260 S, Broad Street, Philadelphia, U.S.A., at $1.25, heavy paper binding; $1.50, cloth binding.

Effect of the formation of Silicide, Phosphide, and Carbide in Molten Steel on their Equilibria with Oxides

This work by Friedrich Korber and Willy Oelsen and issued as a communication from the Kaiser-Wilhelm-Institut, is divided into six sections, which are briefly reviewed in the following :—

1. The heats of formation of alloys of iron and silicon are determined by a simple though rough method at laboratory temperature and for the whole range of concentrations, by bringing into reaction molten iron and solid silicon, and molten silicon and solid iron respectively in a calorimeter. Utilising the predetermined heat contents of the melted iron-silicon material at 1,600° C., their heats of formations can be found. The importance of a large quantity of heat resulting from the formation of silicide, when dissolving silicon in melted iron, on the metallurgical behaviour of silicon is discussed.

2. The effect of the formation of silicide on the equilibrium between the melted metal, the slag, and the solid silica in the system Fe-Mn-Si-O is pointed out, according to the experimental results of their reactions. They are mainly—

$$Mn + FeO \rightleftharpoons MnO + Fe \quad (1)$$
$$Si + 2FEO \rightleftharpoons SiO_2 + 2Fe \quad (2)$$
$$Si + 2MnO \rightleftharpoons SiO_2 + 2Mn \quad (3)$$

3. The way in which these equilibria are displaced by adding phosphorus to the melted metal at a temperature of 1,600° C. is investigated. The essential result is that that part of the metal which can be in equilibrium with melted silicates, is diminished, and that part which is in equilibrium with solid silica is increased. The capacity of iron and manganese for reducing silicon from the silicate slag and from the solid silica, according to the above equations (2) and (3), is diminished.

The phosphides of iron and manganese are present in the melted material, and therefore the reaction effect of both elements with the silica decreases considerably; on the other hand, less iron and manganese remain in the melted material for combining with silica, and the reaction effect of silicon increases.

The influence of the addition of phosphorus in the process expressed by equation (1) is much smaller; for the activity of iron as well as manganese is diminished by the formation of phosphides.

4. The influence of increasing proportion of carbon on the equilibrium between melted iron and silicate slag, by the formation of carbides, is investigated for three temperatures—1,400°, 1,500°, and 1,700° C. Also, the additions of carbon displace to a great extent the equilibria of the equations (2) and (3), which are shifted largely to the right side as iron and manganese lose much of their capacity for reaction owing to the formation of phosphides and carbides in the melted materials. The equilibrium of equation (1) is not so much affected; obviously, silicon, phosphorus, and carbon do not tend to combine with the manganese in the melted material

5. The displacement of the equilibria of the melted material and the slag in the system Fe-Mn-Si-O, as caused by phosphorus and carbon, is compared with the displacement of the line of solubility of graphite in melted iron brought about by silicon and phosphorus. A far-reaching similarity is established.

6. The results are important in certain questions of processes of ferrous metallurgy. In the quoted paper the following are discussed :—

(*a*) *De-oxidation of Iron Carbide by Manganese and Silicon.*—The large quantities of heat arising from the formation of iron-silicon alloys and manganese-silicon alloys are reasons for not using manganese-silicon alloys as deoxidising agents, instead of ferro-manganese and metallic silicide, by which the quantity of heat obtained can be used for the quicker distribution of the addition.

(*b*) *Oxidation of Manganese and Silicon in Melted Pig Iron and in Melted Steel.*—The equilibria between iron, manganese, silicon, and their oxides are displaced with decreasing temperature in favour of an increasing oxidation of manganese and silicon at 1,680° and 1,530° C., and by increasing the manganese. In practical steel production lower temperatures of 1,200° to 1,400° C. are used. The conditions found out at the higher temperatures, therefore, no longer exist. For pig iron the influence of carbon and phosphorous has to be taken into account, which change the conditions similarly in favour of the silicon oxidation, owing to the formation of carbide and phosphide. Both manganese and silicon react vigorously with the oxygen. It is important, however, whether it is mainly the manganese or the silicon that is oxidised. At higher proportions of silicon only silica would remain besides melted pig iron, and this would also be chiefly formed during the oxidation of pig iron. These results, however, can only be used directly when considering the cause of reaction during the first part of the acid process. The conditions are quite different for the basic process, with starting temperatures of 1,200° to 1,300° C. Here a special investigation has been necessary; the reaction is, so to speak, divided into two parts before and after the complete removal of silicon, which is more quickly reduced than manganese.

The Heats of Formation of Nickel-Silicon Alloys

The same methods are used as in a further paper by Willy Oelsen and Hans-Otto von Samson Himmeletjerva, and the results of both investigations are compared. The heats of formation are higher, and the differences for temperatures of 1,600° C. are greater for nickel-silicon alloys. For the latter, two peaks of the curve of heat which signify the dissociation in their own melted materials, while the curve of heat contents of the ferro-silicon alloys

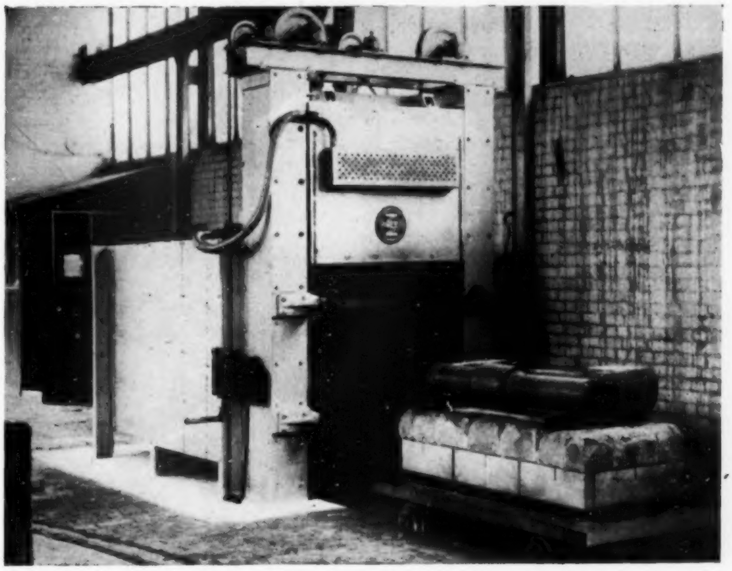
A Communication from the Kaiser-Wilhelm-Institut. Vol. XVIII, No. 9. 1936. Published by Verlag Stahleisen m.b.H., Dusseldorf. Price, R.M. 4,25.

Developments in Electric Heat-Treatment Furnaces

BY

A. G. ROBIETTE, B.Sc.

The popularity of mass-production methods has materially influenced the design of heat-treatment furnaces in recent years. The desire to reduce dependence on the "human element" has led to the development of various automatic and semi-automatic methods of control both of the temperature of the furnace and the handling of the product. In this article the author gives a brief survey of the trend of development, and deals with some outstanding examples of the progress achieved.



Courtesy of Birmingham Electric Furnaces, Ltd.

Fig. 1.—*Bogie hearth furnace for heat-treating forgings.*

RECENT progress in the design and application of electric heat-treatment furnaces takes the form mainly of improvements in furnace design, particularly as regards handling methods, the perfection of existing processes, and a considerable extension in the application of plants of this type. This review will refer mainly to what has been accomplished within the last two years. Previous to that we witnessed the large-scale development of continuous or mechanised hearth furnaces, the successful adoption of forced atmosphere circulation for low-temperature processes, the installation of countraflow recuperative furnaces for various purposes, and the realisation of the possibility of bright annealing or otherwise heat-treating, on a commercial scale, practically all the commoner metals and alloys. In this present survey it is proposed in the first place to deal generally with the trend of development, and then particularly with certain outstanding examples of the progress achieved in the design and application of these furnaces.

Batch Type Furnaces

This class of furnace embodies the conventional box type furnace with or without means for automatic feeding and discharge, salt baths, and any type of equipment in which the material is heated in batches or separate charges as distinct from continuous heat-treatment, has not been radically altered, but in many cases handling methods have been improved, and details of design also modified where called for. Moreover, the use of a protective atmosphere has been applied in many cases, where previously this had been thought impracticable or uneconomical. This phase of the subject, however, will be treated in more detail under another heading. For all operations calling for operating temperatures below 700° C., the use of forced circulation of the furnace atmosphere by means of an internal fan has been found invaluable, and has been widely applied. The resulting advantages include greater rapidity of heating, thus increasing output and also ensuring uniformity of temperature, even in long furnaces.

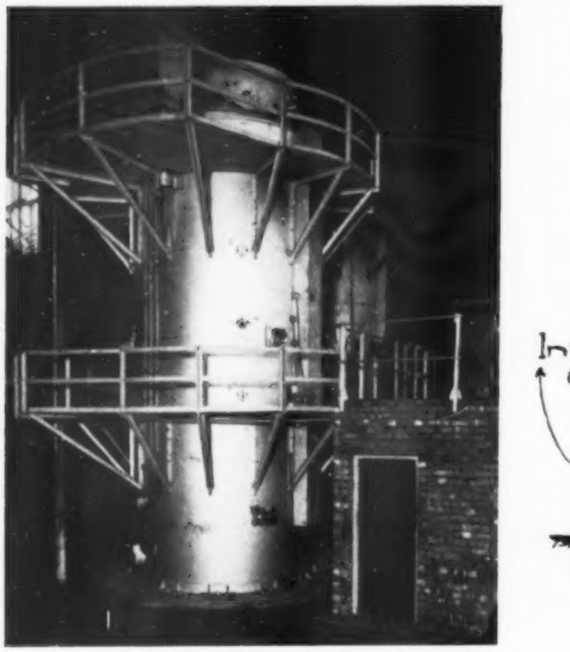
The bogie-hearth type of furnace, Fig. 1, has come into prominence, especially for such applications as the heat-treatment of alloy steel forgings and the annealing of castings. In many cases electrically heated furnaces of this type have been found to be competitive with other methods of heating on a cost of fuel basis. A recent furnace of this type is shown in Fig. 1.

The vertical cylindrical, or pit type, furnace has found considerable favour for the hardening of long forgings. The furnace is of the multi-zone type, it being possible to vary the power input and temperature throughout the height of the furnace. In this way convection effects can be balanced and perfect uniformity of temperature over heights of 30 ft. to 40 ft. or more can be ensured. The outstanding benefit conferred by this type of plant is that it cuts out the necessity for re-treating expensive parts mainly by eliminating the temperature variable. The human element can be further avoided by the fitting of a programme controller which will give any predetermined time-temperature cycle for heating, soaking, and, if necessary, cooling. The heavy-cast type of element in the form of a patented grid section has been successfully used in conjunction with this type of furnace, and has the advantage of extreme robustness even to the extent of large forgings coming into accidental contact with the elements. A furnace of this type is illustrated in Fig. 2. It has a heating chamber 3 ft. in diameter and 20 ft. 6 in. high.

For the solution treatment of aluminium alloy tubes, sections and sheets, many furnaces have been constructed with ingenious charging and discharging devices. The material in the case of long tubes or sections is placed in a skip which is run into the furnace on idle rollers by means of a rapidly moving endless chain, which also serves to discharge the skip on to a roller table. This latter is situated above the quench tank, and the table is first tilted and then rapidly lowered into the water. The whole operation of discharging and quenching is only a matter of seconds. Similar devices are in use for the solution treatment of aluminium alloy sheets. In every case, of course, the furnaces are fitted with a number of circulating fans, and the temperature is controlled in zones.

Salt baths have certain advantages for low temperature heat-treatment, especially in the manufacture of heat-treatable and aluminium alloys. It is relatively easy, by proper design, to ensure uniformity of temperature and the rapidity of heating results from contact with the molten salt. Many of the disadvantages of the older types of salt-bath, including explosion risk, uneven heating, and pot failure have been overcome by a new design of bath invented

by Kärcher in Germany, a diagrammatic illustration of which is shown in Fig. 3. The bath employs immersion heaters enclosed in tubes which are located at the bottom of the container to ensure a maximum convection effect. This causes efficient mixing of the salt as well as very uniform temperature distribution. The salt container has an outer shell, and should the inner container or bath fail, an alarm device is brought into operation. The outer shell serves to prevent any of the salt entering the insulating material. The elements are made removable from the tubes, and in the event of premature breakdown can be replaced while the other units are in operation. In other words, the failure of a single unit does not immobilise the plant. The elements are so disposed that the " slum "



Courtesy of Birmingham Electric Furnaces, Ltd.

Fig. 2.—Vertical pit type furnace, with a second furnace in background.

or residues fall through to the bottom and do not cause overheating of the elements. This type of bath has been found invaluable to the aircraft constructor who is faced with the difficult problem of having to treat rapidly and uniformly a large variety of materials differing in shape and size.

Continuous Furnaces

The continuous electric heat-treatment furnace has many variations of type, and employs such devices as conveyers (overhead and belt), pusher gear, driven roller hearths, walking beams, rotary hearths, and rotary drums, and all these types have been well established for some time past. Little radical modification has been necessary in their design, apart from the incorporation of improvements in construction, but the main feature of interest is their increasing application. Many installations have recently been put into commission for such purposes as the reheating of brass, copper, and aluminium alloy billets for rolling or extrusion—applications which were once considered as being among the cruder forms of heat-treatment. Several furnaces are being used for the continuous normalising of black or hot-rolled strip, as well as for the annealing and normalising of cold-rolled products. The enormous increase in production which has recently been witnessed in the manufacturing industries has occasioned the installation of such a variety of continuous furnaces for hardening and annealing, etc., that it would be impossible to describe these within the compass of this review.

As has been pointed out, mechanical loading and discharging devices are among the major improvements in continuous furnace practice. For the hardening of complicated parts, such as crankshafts, axles, and any article which has to be quenched in a special manner to preserve its shape devices are in use which automatically receive the parts as they leave the heating chamber, and ensure uniform quenching in a predetermined manner. Parts that are heated for hardening on trays have always presented a problem in mechanical manipulation. This has been solved by what is called a " pan-dumping " system, whereby the pans or trays when they reach the discharge point in the furnace are automatically tilted, and they shoot or discharge the contents into the quench tank whilst the trays are retained or held by a mechanical device and then returned hot to the charging end. In the case of the rotary hearth type of furnace, which has been successfully employed on this system, the trays are, of course, returned in the furnace.

Much thought and development has been directed towards perfecting recuperative systems, and large roller hearth furnaces have been built in this country employing the contra-flow principle. Its application to pusher furnaces is, of course, well known and widely practiced. Extremely high thermal efficiences have been attained, and the extension of this field of development seems certain where the additional capital outlay is small compared with the savings realised.

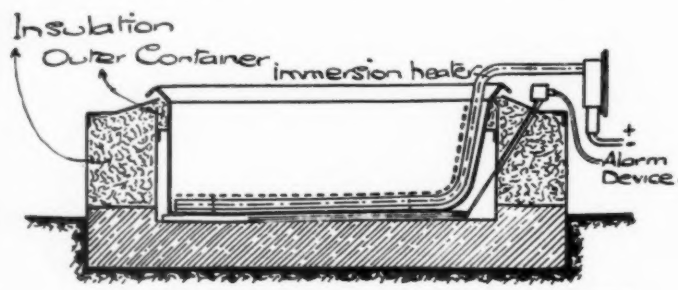


Fig. 3.—Salt bath with immersion heaters (Kärcher Patent).

Protective Atmospheres

Undoubtedly the largest measure of progress has been evidenced in the development and application of artificial protective atmospheres to prevent oxidation and other surface defects, such as decarburisation. Nowadays few manufacturers are content with the conventional open furnace in which the work is allowed to scale more or less freely. The modern tendency is to specify furnaces in which oxidation is partially or completely suppressed and decarburisation eliminated. With these objects in view, extensive research work has been prosecuted, and it is no idle claim to say that to-day practically every commercial metal or alloy can be bright annealed or otherwise heat-treated on a commercial scale by processes which are almost automatically controlled and in most cases show considerable economies over open atmosphere methods. Within this past year it is estimated that at least 35% of the furnaces supplied in this country are adapted in some form or other to atmosphere control.

Dealing first with the artificial atmosphere which is generated externally to the furnace, this in most cases has either ammonia or coal gas as its source, although other fuels are being used successfully and economically for special purposes. Ammonia in its dissociated or subsequently combusted form gives the purest and least complicated gas mixture, consisting only of a nitrogen/hydrogen mixture. If burnt ammonia is used, effective drying, such as that which is possible by passage over activated alumina, is essential for the annealing of readily oxidisable metals, such as those containing chromium, manganese, or zinc. Cracked ammonia is essential where a high hydrogen content is required for reducing purposes, but burnt ammonia

is almost half the price, and is safer to use, especially with unskilled labour, owing to the elimination of any explosion risk. Recent work has shown that in many cases it is possible to recirculate or regenerate the ammonia to the extent that 90% or more of the atmosphere is conserved and recirculated. This means that the cost of the atmosphere is about 10% of the cost of plain burnt ammonia. Plant of this type has latterly been put into operation with considerable success.

Partially burnt coal gas, subsequently purified, is being used for a variety of purposes, including the bright annealing of copper and high copper alloys, mild steels, and nickel alloys. It is only possible to use coal gas by a very thorough method of sulphur removal, which is done in two stages to eliminate both inorganic and organic sulphur compounds. A few grains of sulphur in the gas entering a bright annealing furnace would, within a very short time, destroy all the heating elements and any other furnace parts containing nickel. The introduction of efficient cleaning of the gas suitable for its use in this direction is one of the major developments recently brought about. Apart from this precaution, it is necessary to control the moisture content as well as the content of reducing constituents, so that the gas will not be oxidising through all the stages of heating and cooling. Partially burnt coal gas is being employed for clean and scale-free hardening, as well as for bright annealing. Other gases are being successfully applied to the bright annealing of high-carbon steels and to the bright hardening of production parts. The carburising constituents of the gas are balanced against those having a decarburising tendency and extreme degrees of dryness are essential.

The above constitutes a brief review of the position as regards the question of atmosphere, and it only remains to consider the type of plant in use and its application. The simple batch type of furnace for the tool-room and the production hardening and annealing shop, is now being very largely adapted to atmosphere control, and in most cases an externally generated atmosphere is admitted to the furnace. If the door is frequently opened, a high velocity gas curtain or flush is employed to prevent the entry of air during charging and discharging. Not only is oxidation minimised, with a resulting saving in cleaning processes, but decarburisation in most cases is suppressed, thus dispensing with the need for final lapping or grinding.

Turning to true bright-annealing furnaces, the bell type has come into prominence for a wide variety of applications. It is a well-known construction employing a multiple of fixed hearths on which the charge is placed. The hearths are covered by a thin heat-resisting hood or container, sealed around the bottom rim by a trough of liquid, and the furnace is made movable to be placed over any of these hearths. The protective gas is passed into the container throughout the heating and cooling periods. The improvements in this type of plant include the use of fans to circulate the atmosphere, and these fans have been made suitable for operation up to 750° C., which covers the annealing of practically all high and low carbon steels. In certain cases advantages have been found to accrue from placing elements inside the gas-tight container, to ensure more rapid heat transfer, and the use of forced cooling by means of sprays and cooling coils has effected a considerable shortening of the cycle of operation. Besides increasing the speed of heating, forced circulation has brought about two outstanding benefits, the first being that the size of container is now not limited by considerations of temperature uniformity, it being well known that in the older designs employing a still atmosphere there was a limit to the diameter permissible without causing too great a temperature gradient from the outside to inside. The second advantage is that lubricants can be very much more readily liberated and removed at a low temperature from the material to be annealed, and consequently staining and carbon deposition from these causes can be minimised.

This is a very serious consideration in cases where the

Courtesy of Birmingham Electric Furnaces, Ltd.

Fig. 4.—Recent bell type furnace for bright annealing steel strip.

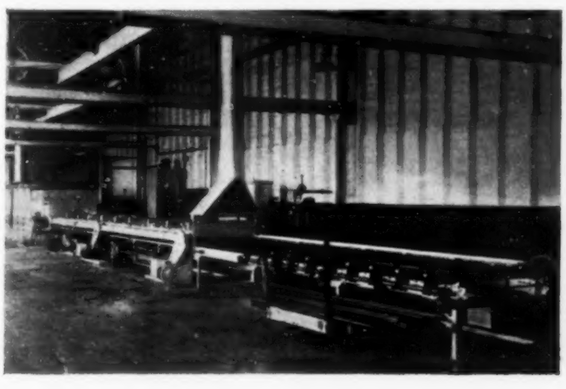
cost of degreasing cannot be faced. Recent plant of this kind include several installations for the bright annealing of copper wire and strip, the bright annealing of mild steel and high-carbon steel wire and strip, and also for magnetic materials (Fig. 4).

Turning to continuous furnaces, those used for production hardening are the same as those described under a previous heading. Practically all these types have in many cases been adapted or designed for protective atmosphere work, and where automatic quenching without bringing the material into contact with air is in use, virtually bright hardened results can be obtained. Furnaces of the conveyer, roller hearth, rotary hearth and other types are already in use, and the wider knowledge of these processes will undoubtedly revolutionise existing shop practice.

True bright annealing in continuous furnaces is undoubtedly one of the most important developments of this past two years, and the success which has attended the operation of this type of plant has considerably extended its scope. The first furnaces of this type employed were of the wire-mesh belt-conveyer pattern, and were used principally for pressings and stampings of brass and steel. They were afterwards used for the annealing of non-ferrous strip and sheet. The more recent applications of this plant embrace electric furnace brazing, in which steel or other parts are joined together by a brazing alloy, which latter melts in its passage through the furnace and runs by capillary attraction into the joint, without in most cases the need of a flux. As was predicted, this process is rapidly supplanting other methods of fabrication, such as rivetting, torch-brazing and soldering, and is the means of avoiding complicated machining operations by brazing together the separate components of an assembly. This type of furnace operates when used for the copper brazing of steel parts at a temperature of 1,130° C., and much work has been done in the past few months to perfect designs and develop new

Fig. 5.—Continuous normalising and annealing of tubes. New electric heat-treatment furnace for normalising welded pipe joints.

Courtesy of Birmingham Electric Furnaces, Ltd.



alloys to improve the life of the conveyer belt and other furnace parts, subjected to varying stress in a reducing atmosphere. This work has produced very satisfactory results, and it is estimated that the life of belts has been doubled.

Another noteworthy advance has been the perfect bright annealing of austenitic stainless steels in the form of strip, tubes, and wire, at the same time preserving the desirable rate of cooling to inhibit the precipitation of carbides. Furnaces are now operating on these and similar chromium-containing alloys for strip, wire and tubular products with perfect results. A year or two ago this problem was considered by the majority of metallurgists as being insoluble. It is believed that these furnaces are the first to be operated in the world on this particular application.

The advent of bright normalising of steel strip in continuous coils and straight lengths is yet another achievement to be recorded. Practically all mild steel strip was previously annealed by packing in boxes. Short time, continuous treatment has several obvious advantages, but its importance metallurgically is that strip lightly cold-rolled can be normalised to prevent grain growth whilst heavily cold-rolled material can be normalised at a higher temperature to increase grain size, over that which would be obtained by annealing. Moreover, hot-rolled strip can be descaled at the same time as normalising, and the latter treatment is essential to be certain that hot-rolled material is suitable for drastic cold forming. Furnaces of the roller-hearth type are used for this work, and the same type is being used for the annealing and normalising of tubes, both ferrous and non-ferrous. A furnace for the bright annealing of tubes is shown in Fig. 5.

It is noteworthy to record that we have more furnaces of this type operating on steel strip in this country than elsewhere, and yet this development has only taken place within the past twelve months.

The progress recorded in the foregoing covers only the salient features, but it undoubtedly serves to emphasise what rapid strides have been made. In continuous furnace practice we are as yet by no means ahead of our American rivals, due probably to the fact that their mass production methods lend themselves to the application of mechanisation to the utmost degree. In the field of the bright annealing we are more than holding our own, even though the application of these processes was initially slow to take hold.

NOTE.—Some of the designs and processes described in this article are proprietary.

Some Aspects of Industrial Hygiene

A DEPARTURE was made from the usual technical nature of the subject at a recent meeting of the Midland Metallurgical Societies, when Howard E. Collier, M.C., M.B., Ch.B., Head of the Department of Industrial Hygiene and Medicine at Birmingham University, delivered an interesting and informative lecture. At the outset of his remarks, Dr. Collier pointed out that the responsibility of industrial management for the health of thousands of workers was a great one, not only from the standpoint of the workers themselves, but also from the standpoint of the benefits accruing to industry by healthy workpeople. If the worker was healthy and comfortable the standard and output of work would be very much greater than if the converse was the case. The subject was, therefore, also an economic one.

Referring to the main causes of disablement in the metal industries, Dr. Collier stated that the chief were found to be sepsis, chest complaints, slight accidents, and nervous disorders, and the diseases which caused mortality among metal workers, in order of importance, were tuberculosis, pneumonia, and other respiratory diseases. Those facts gave them the general background of the problems of industrial hygiene, and if he said that chest diseases were the most serious and difficult part of the mortality which had to be controlled, and that dirt diseases and chest complaints were the greatest causes of disablement, they would have a general idea of the problem which confronted those engaged in hygienic research.

With regard to the causes of mortality among metal workers as a result of the diseases mentioned, these were three: Social causes—that was, overcrowding and incorrect feeding, which was not a responsibility of industry; also exposure and minor respiratory disorders, which were the responsibility of industry. As to the chances of infection, many cases were, of course, due to home infection, but many could be attributed to works' contact and infection. The question of the tubercular workman was, for instance, very important, but there was also the risk of disease carriers, and this type of person was a real menace to health. Danger was always aggravated by overcrowding in workshops, by moist atmospheres, both of which resulted in the danger of a prevalence of minor respiratory disorders, and these were, therefore, undoubtedly the root problem of health in metal industries.

Turning to the problem of how to overcome these dangers, Dr. Collier pointed out that the human body could adapt itself quite successfully to a wide variety of conditions, but only if its internal temperature remained practically constant. Very sudden, repeated, or extreme changes of temperature may cause this regulation to break down, or make it difficult for a steady internal temperature to be maintained. Such changes of temperature caused the mucus membranes of the nose, throat, and chest to be first flushed, then contracted, now moist, and then dry. The combined effects of these sudden changes rendered these organs to be more sensitive and lowered their resistance to infection from germs. When, in addition to this, there were the added irritations of foreign bodies, such as dust, the ground was well prepared for minor respiratory disorders first, and for the more serious kind later.

With regard to temperature changes and the amount of dust, there were certain basic standards which should always be adhered to, if possible. For instance, in the case of sedentary workers, the temperature should be maintained between 68° and 72° F.; for semi-active workers, between 60° and 68° F.; and for active workers, below 65° F. At the same time, air movement for the three classes should be: Sedentary workers, ½ ft. to 3 ft. per sec.; semi-active workers from 3 ft. to 5 ft. per sec.; and for active workers, 5 ft. to 15 ft. per sec.; and the humidity of the atmosphere should be between 40 and 70%. Also, sedentary workers should have the air replaced four or six times per hour; semi-active workers, 10 times per hour; and active workers, 20 times per hour. It was, therefore, obvious that the key problem for the maintenance of health was ventilation, using that word in the sense of the provision of clean air, at a proper temperature, and moving at the correct rate through workshops, rooms, etc.

Other points which would in course of time make a great difference to the health of workers was the design of new factories, the reconditioning of old factories, the probable health effects of new substances or new methods, and the understanding or handling of human relationships within the industrial organism.

Developments in the Tin Industry

By A SPECIAL CORRESPONDENT

General developments in recent times, in the tin-consuming industries were briefly discussed in an earlier issue. The present year has seen progress in some of the advances that were then in their infancy, a few of which are discussed in this article.*

THE increase in world tin consumption during 1936 can be attributed largely to the tinplate industry, which used 13% more tin in 1936 than in the previous year, but there were also important advances in other industries, which used in the aggregate 9% more tin than in 1935. It is interesting, therefore, to discuss tinplate at greater length, particularly with reference to recent developments in the industry in U.S.A.

Important changes in the rolling of steel sheet for tinplate which have developed during the last two or three years have made further progress. Cold reduction of the steel sheet, which has become definitely established in U.S.A., would appear likely to increase. The chief disadvantage of cold-reduced sheet, that of "fluting" or not bending smoothly, is being overcome, and future improvements may be expected. The ductility of cold-reduced tinplate is adding materially to the manufacture of better stamped products.

As a consequence of this development, mechanical improvements in the ordinary method of pack rolling are being introduced. Changes in the composition of steel for pack rolling are also being made in order to meet the more rigid specifications for cans for some foods, and to produce greater ductility.

Improving the Quality of Tinplate

The continuous efforts to improve the quality of tinplate have also brought about changes in other equipment. A development of the last few years, now considerably adopted in U.S.A., is the substitution of electrically or gas-tube heated portable covers for fixed annealing furnaces. A light sheet-iron or alloy-steel cover is placed over the charge of coiled strip or stacked sheets, which may consist of 50 tons or more of material. The portable heating cover is set in place, and the charge efficiently and uniformly heated. After the heating and soaking periods of perhaps 30–40 hours, depending on the width of the sheets, the cover is withdrawn (leaving the protecting inner cover), and immediately used to heat another stack of material. In this way, one portable furnace may serve three or four stands. The material may be cooled more quickly without injury, and fuel utilised far more efficiently than with heavy cast-iron covers. Moreover, by using gas-fired radiant tube or electric elements, heating is better controlled and more uniform.

Controlled non-oxidising atmospheres are being used to protect the charge being annealed from oxidation while it is hot. Generally a dehydrated, partially combusted gas, such as cracked natural gas, is used in U.S.A., because of its cheapness and availability for large-scale use. This gas is passed into the chamber around the charge throughout the annealing cycle. The use of a protecting gas of some sort has been suggested, and used to some extent for many years, especially during the cooling part of the cycle, but it has been only recently that effective cheap gases have been developed and the field of bright annealing proved commercially satisfactory.

Attention is also being given to operating normalising furnaces with a controlled non-oxidising atmosphere. Such bright normalising furnaces operate with a slight positive internal gas pressure to discourage air penetration, and with a mechanical entrance barrier, such as one or more asbestos sheets hung in the passage way.

This method of softening sheet for tinplate has excellent possibilities for continuously softening cold-rolled steel strip and preparing it for tinning without pickling. Such a procedure, however, is still in the development stage.

In keeping with the modern tendency for rapid continuous production, continuous normalising and pickling are being done more and more. Electric heating by resistance or by induction, offers possibilities in the normalising field. Electrolytic pickling of steel sheet in a fused caustic bath offers promise for the future of a much cleaner product for tinning.

Under some conditions where pickling is not desirable, mechanical abraders that grind away or blast off scale and produce a clean metal surface are being used. The machines may find increased use in the future.

Foremost in a consideration of future tinning improvements is the probable growth of continuous tinning of steel strip. Although terne plate is now being commercially produced in continuous strip of satisfactory width, continuous tinning of wide steel strip has scarcely reached the commercial stage. Considerable experimentation is in progress, however, and this development should arrive within a very short time.

The use of immersion heaters in the tin pot, near the entrance end, has proved very satisfactory in many plants, and soon should be considered standard practice. This gives automatic heat control that may be very closely regulated.

Tinplate made by electro-deposition of tin is just becoming a commercially available material. Uniformity of coating with remarkably few imperfections, even with very thin coatings, is claimed. Improvements in this relatively new method of tinning may be expected as difficulties in commercial production are overcome.

There has been a considerable increase in the use of tinplate for canning, which is due not only to a greater consumption of canned food, but also to an increase in the number of products so packed. The canning of beer, which was started last year in U.S.A., has attained considerable proportions, and has spread to England and other European countries. This development has been followed in U.S.A. by the canning of Californian wine, and there is promise that other beverages will be sold in cans in the near future. The packing of motor-car lubricating oil in sealed cans is another interesting development that promises to become of great importance in Europe. It already consumes a great amount of tinplate in U.S.A.

The past year has seen considerable expansion in the use of the new alkaline detergent for tinned ware. This consists of sodium carbonate and sodium sulphite. The latter removes oxygen from solution and prevents corrosion of the tinned surface by alkali, while the detergent properties of the sodium carbonate are unimpaired. The electro-deposition of bronze from alkaline baths is now finding application, particularly as an undercoating for a chromium deposit. Of great interest to the tin industry are the improvements recently made in tin-base bearing alloys by modifying the composition. The modified alloys are now being introduced, and the risk of substantial substitution of other materials for tin-base alloys has diminished.

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* Metallurgia, Vol. 13, No. 74, pp. 61–2.

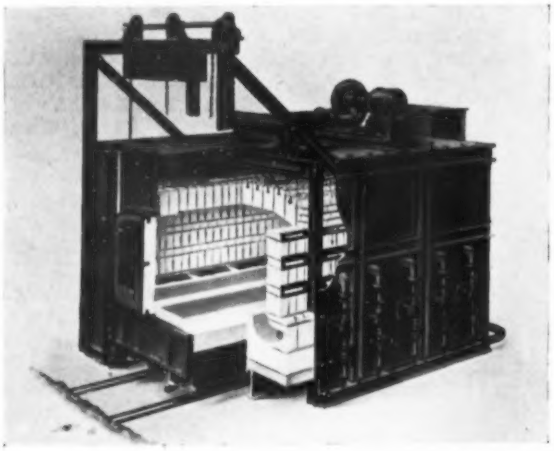
Tin Researches

During the year the International Tin Research and Development Council has continued its researches on many aspects of the uses of tin in industry and has published numerous papers, particularly on the factors influencing the porosity and corrosion of tinplate, the fundamental properties of tin and the properties and constitution of tin-rich alloys, the detection and determination of tin in solution and in alloys, the hot tinning of copper, the properties of vitreous enamels opacified with tin oxide, and the use of tin compounds in retarding the oxidation of various oils. Much of this work has already been reviewed in these columns. An interesting innovation, which is shortly to be published, is the production of a hard black film on tin and tin-base alloys by anodic treatment in a hot solution of an alkali phosphate. By stopping-off certain parts of the tin surface, a pleasing contrast is produced, which lends itself to decorative effects. The corrosion-resistant properties of the film are under investigation.

Furnace Settings in the Iron and Steel Industries

A revolution in the principles of industrial furnace design and construction is indicated by a recently developed air-jacketed furnace, suitable for gaseous, liquid, and solid fuels, the entire construction of which consists of suspended walls and arches. In this article the furnace is described and its advantages discussed.

THE standard furnace setting used to-day in the iron and steel and general engineering industries for heat-treatment, forging, and drop-stamping, billet-heating, reheating, annealing, and similar operations is designed and constructed on obsolete lines, with sprung arches and simple type solid walls, consisting of bricks or blocks piled on one another. This applies, however, to many other industries, and equally to gaseous, liquid, and solid fuel firing, and for this reason the nett thermal efficiency is very low, within the range of, say, 25%—40% for good conditions with recuperators, and well below 25% in a large number of cases, partly because of heat loss in the walls. Consequently great interest attaches to a striking new advance in industrial furnace construction, known as the "Liptak Air Jacketed" system, that has been developed by Liptak Furnace Arches, Ltd.



Diagrammatic view of a jacketed gas-fired annealing furnace.

Essentially, this consists in building the furnace, of any desired shape and size, of relatively thin suspended air-cooled refractory walls and suspended arches, attached to a steel framework, and including a self-contained motor-driven fan, with or without recuperators for supplying the air for combustion. Firing also may be with gas, including coke-oven gas, blast-furnace gas, and producer gas, using low-pressure turbulent "Gako" burners, oil, or solid fuel, such as coal or coke.

The air passes through a space or jacket all round the setting between the roof and the suspended refractory walls and a thin outer casing, and is pre-heated to about 300° F., whilst the roof and walls are kept cool, not over, say, about 750—850° F. at the back of the brickwork, under conditions of 2,200°–2,400° F. at the face—that is, of the combustion space.

When recuperators are used, the pre-heated air is passed from the jacket through the recuperators to the combustion chambers or burners, being raised from 300° F. to, say, 500–600° F., depending on the conditions. Also, the self-contained recuperators fitted when desired are of an advanced design, either on the unit or the battery principle, consisting of special heat-resisting steel tubes in the combustion discharge flues, forming an integral part of the furnace setting. Recuperators of this design only occupy a very small space, whilst they are highly efficient, not only as regards rate of heat transmission, but also because, unlike firebrick recuperators, they are permanently leak-proof.

As a result, the average nett saving obtained by this new air-jacketted system of furnace construction, along with recuperators, is at least 15% of the fuel bill, compared with ordinary recuperator furnace settings when in good condition, or 30–35% with ordinary non-recuperator settings. Very often, however, the saving exceeds the above figures, since many furnace settings are not kept in good condition.

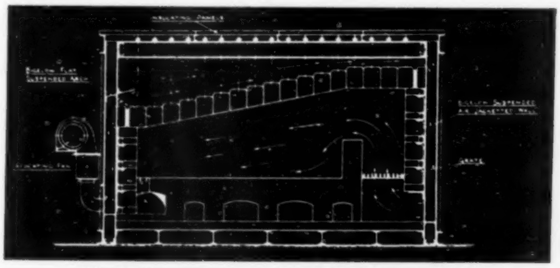
Also, more accurate control of the temperature is obtained, the furnace setting is much lighter in weight, so that less time is required to heat up, whilst no heat-insulating material is required, either within or directly outside the main walls, it only being necessary in the shape of the outer casing, enclosing the air space.

It will be remembered the basic principle of the suspended wall and arch is the use of standard interchangeable refractory blocks provided with a slot, which are hung from cast-iron or steel framework. Consequently, a flat arch or roof of almost any width can be constructed, merely depending upon the strength of the girders, quite different from the sprung arch which is limited in width to, say, 8–10 ft., because an increase in the latter figures would need an arch reaching to a great height.

The suspended wall, on the same lines, consists of refractory blocks suspended from the steel framework, having the necessary vertical and horizontal sections and hangers.

This type of combustion chamber is now largely used for water-tube boilers, and in this connection the firm are well known for their "Liptak" suspended-arch construction, with two rows of interlocking blocks, one above the other, and "Bigalow" suspended construction, which has either one or two rows of blocks attached direct to the steel

supports. The latter is used for industrial furnace settings, with double rows of wall blocks, so that there are no through joints traversing the walls, which prevents air leakage, and this general method of constructing walls and arches has such great advantages that the solid brick box type of combustion chamber is completely out of date for water-tube boilers, and the same now applies to general industrial furnaces.

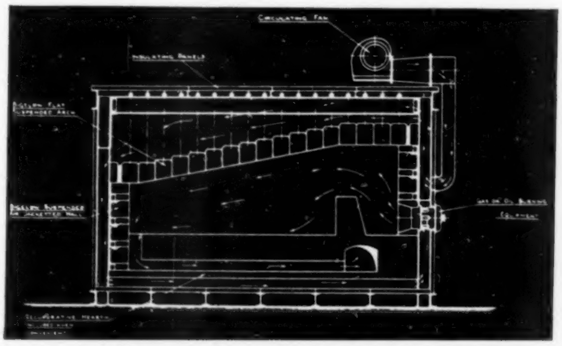


Typical arrangement of coal-fired furnace with air-jacketed system.

For example, in the suspended principle, each block is entirely independent of its neighbours, so that any one can be replaced immediately without disturbing the structure as a whole. Also, for the same reason, there is no strain on individual blocks, each of which is free to expand and contract, and is not subjected to compression strain from other blocks, especially from those above, or to thrust from arches.

As a result the maintenance cost of the suspended wall and arch furnace setting is much less. In the new design also the principle of air cooling is a huge improvement as regards reducing wear and tear on the firebrick wall and increasing the efficiency of combustion, aided also by the easy control of the circulating air.

The different temperature conditions in a suspended wall and a solid wall furnace setting are well illustrated by the results of detailed investigations that have been undertaken in the field by Liptak Furnace Arches, Ltd., on a gas-fired non-recuperator type of setting.



Typical diagrammatic arrangement for gas- or oil-fired furnace of air-jacketed design.

A typical solid furnace wall has, say, 9 in. firebrick, 3 in. insulating brick, and 4½ in. red brick—that is, a total of 16½ in.,—and normal temperature conditions are 2,300° F. (1,260° C.) in the furnace—that is, the face of the firebrick ; 1,750° F. (954° C.) at the juncture of the firebrick and the insulating brick, and 280° F. (138° C.) at the back of the red brick—that is, the outer wall in contact with the atmosphere. The mean temperature also of the 9 in. refractory wall also is about 2,000° F.

With the suspended furnace-wall furnace, however, the conditions are quite different. As before, the furnace temperature is 2,300° F. (1,260° C.), and the suspended wall is of 9 in. firebrick, but there is now a 6 in. air space, followed by the thin panelled outer casing of insulating material.

The average temperature of the air passing through the jacket, both the roof and the walls, to the burners is 300° F. (149° C.), and because of pronounced cooling effect the firebrick is only 800° F. (426° C.) at the back, with a mean refractory temperature of about 1,500° F. Also, the outer casing wall is only 160° F. (71° C.) outside, facing the atmosphere. The resulting heat economy is obviously very great, especially as the suspended wall is only about half the thickness, the calculated saving being 30–40% of the total heat.

Thus, the solid wall, 16½ in. thick, stores 41,250 B.th.u. per sq. ft. after soaking, whereas the suspended wall of 9 in. thickness, with 6 in. air space and 2 in. casing thickness only stores 26,350 B.th.u. per sq. in. Further, the maximum heat loss per hour from the solid wall is 650 B.th.u. per sq. ft. when soaked, and from the air-cooled suspended wall 250 B.th.u. per sq. ft.

An important point is the enormous amount of heat absorbed by the solid wall, because of the much greater thickness and weight, and the higher mean temperature.

In this connection, valuable information has been published by Sir Robert Hadfield and R. J. Sarjant (*Refractories Journal*, February, 1934) and R. J. Sarjant (" Transactions of the Ceramic Society," March, 1933, and September, 1934). They show that 30–45% of the total heat supplied to standard industrial furnace constructions is lost in the brickwork, partly by surface losses from the outside to the atmosphere, but chiefly by heat storage in the linings. Also, as a result of extensive experience, they are of the opinion that an average industrial furnace with recuperators in good condition operates at 25–30% thermal efficiency, with 30–45% lost in the walls, as already indicated, and 20–25% in the waste combustion gases when using recuperators.

Finally, it may be stated that a number of the new air-jacketed suspended arch and wall furnaces are already operating with great success for various operations, including drop-stamping, annealing, steel castings, continuous billet-heating, and hardening and tempering springs.

International Association for Testing Materials

AT the Congress held in Zürich in September, 1931, the International Association for Testing Materials accepted an invitation from the Committee representing British members to hold the next Congress in Great Britain. Arrangements are now in progress for the Congress to be held in London on April 19–24, 1937.

The object of the Congresses held by the International Association for Testing Materials is to obtain international co-operation in the study of materials and their testing, and to provide facilities for the exchange of views, experience and knowledge with regard to all matters connected with this subject. The London Congress will be of considerable scientific and industrial importance, particularly in view of the length of time which has elapsed since the study and testing of materials were last reviewed on an international basis.

The proceedings at the forthcoming meeting will be based on selected papers, which, by invitation of the Group Presidents appointed by the Permanent Committee, have been contributed by leading authorities in their respective fields in the principal countries throughout the world. Over 200 papers have been promised from authorities in some 20 countries.

Copies of the list of papers can be obtained on application to the hon. secretary, Mr. K. Headlam-Morley, 28, Victoria Street, London, S.W. 1.

Sir Robert Hadfield, Bart, F.R.S., who recently celebrated his 78th birthday, has given £1,000 to promote the compilation of mineral brochures by the Imperial Institute of Mineral Resources. Sir Robert is a member of the Advisory Council of this Institute.

Business Notes and News

G.W.B. Furnaces, Ltd.

Owing to the very considerable increase in the business of G.W.B. Furnaces, Ltd., and that of their associated company, Wild-Barfield Electric Furnaces, Ltd., it has been necessary to provide increased accommodation, and as from January 1, 1937, the registered offices of this company, including Sales Department, Drawing Offices, and Accounts Department, will be moved to Belgrave House, Belgrave Street, London, W.C. 1. Telephone Nos., Terminus 5191-2. Telegraphic address: Gibwildbar, Kingscross, London.

The company's works will remain as at present at North Road, Holloway, Dudley, Worcs., and Anne Road, Birmingham. It should be noted that Messrs. Wild-Barfield Electric Furnaces, Ltd., will remain at Elecfurn Works, North Road, Holloway, N. 7, as hitherto.

Developing the North-East Area.

The North-East Development Board has, with the approval of the Commissioner for Special Areas, decided upon an expert investigation into the lead resources in a portion of Teesdale. Lead mines were formerly worked in that area, and an impression in the vicinity that substantial quantities may still remain unworked has given rise to this investigation.

Consideration is also being given to the desirability of an expert investigation into the resources of barytes and fluorspar in the area. These investigations will be under the auspices of the Technical Advisory Committee of the Board.

In the last month the Board has received four inquiries from industrialists. One of these is being put in touch with a local concern with a view to the manufacture in the North-East of cast-iron tanks; another was from Brussels from an inquirer desiring to begin the manufacture of rubber soles and heels in the area; the third was an inquiry for a tannery, and the fourth came from Sweden from a manufacturer of musical instruments. The necessary information has been supplied in each case.

The North-East Board's Stand at the Northern Exhibition of Inventions in Newcastle produced 44 inquiries, 39 of them from exhibitors seeking to be put in contact with industrialists likely to manufacture their inventions. Three were seeking additional capital; one exhibitor desires the advice of the Board's Technical Advisory Committee, and a visitor to the Exhibition is seeking additional capital for his own business. Negotiations in connection with some of these inquiries are proceeding.

Surface Coatings on Aluminium and its Alloys: International Competition.

In order to extend the fields of application of aluminium and its alloys, a competition has been inaugurated by the Bureau International des Applications de L'Aluminium, 23, bis, rue de Balzac, Paris (8e), France, with the support of the following European aluminium producing companies:—L'Aluminium Francais, 23, rue de Balzac, Paris; Ste. Ame pour L'Industrie de L'Aluminium, Neuhausen, Switzerland; the British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4; and Vereinigte Aluminium Werke, Lautawerk, Germany.

The competition is open to inventors in all countries, and is designed to encourage researches into the chemical production of surface coatings on aluminium and its alloys, with the object of evolving a process which should constitute an improvement on the process known under the name of the M.B.V. process. This treatment consists in immersing the articles for about 10 mins. in a hot solution of anhydrous sodium carbonate and sodium chromate in distilled water, and subsequently washing the articles in hot or cold water.

It should be noted that the competition does not cover processes of protection by lacquers, varnishes, paints, waxes, or similar applied coatings; the surface coatings must be obtained by chemical means, and without the aid of electric current. They must be applicable to both aluminium and its alloys, although it is not essential that identically the same process should be employed.

The author of the process, considered by a competent jury to be the best and most economical, will be awarded 25,000 French francs. Should the jury consider two or more processes to be of equal value, the prize will be divided. Full information regarding the competition may be obtained from any of the companies mentioned above.

Colville's Try New Mill.

The new continuous bar and rod rolling mill, installed at the Dalzell Works of Colville's Ltd., has been given an experimental run. Much of the work in connection with this mill has been done by Colville's, although the bar-handling and wire-rod coiling equipment was designed and supplied by the Maschinenfabrik Sack, of Dusseldorf; this company is also erecting a large blooming mill at the Glengarnock Works of Colville's, Ltd.

The continuous mill is the first of its kind to be erected in Scotland, and comprises eighteen stands. After the trial run some adjustments will doubtless be necessary, but it is hoped to operate the mill on a production basis early in the New Year.

A Lead Products Technical Information Bureau.

At a recent meeting of the Lead Industries Development Council, the inauguration of a lead products Technical Information Bureau was announced by the chairman, Mr. H. S. Tasker. The Council, it will be remembered, was established some months ago under the auspices of the majority of the producers and manufacturers of lead sheet and pipe, white lead, red lead, and lead oxide of this country. Its general aim is to develop lead as a modern material, capable of competing successfully with kindred building materials and to increase and extend the use of lead and lead paints in every useful field of application. In the field of research, for example, it aims not only at encouraging new and improved methods of practice, as in lead-burning and in the mechanical application of lead paints, but also at developing the application of new products, such as the various lead alloys.

The new Bureau will function as the distribution centre for information on lead and lead paint work. Its future publications will include such topical subjects as: Lead for Sound Vibration Insulation, Lead for X-ray Protection, the use of lead paints in the protection of ship-building materials and in the treatment of steel-work used in large-scale building enterprises. Through its medium, the Council is also to encourage the standardisation of lead products in the belief that this will help both to simplify the work of craftsmen and to widen the market for manufacturers. The address is: Technical Information Bureau, the Lead Industries' Development, 19, Hobart Place, Eaton Square, London, S.W. 1.

Ebbw Vale Steelworks Reconstruction.

Several orders have already been placed in connection with the £5,000,000 reconstruction scheme by Messrs. Richard Thomas and Co., Ltd., which is to be carried out at the Ebbw Vale Steelworks. These include a complete by-produce coking installation, a large boiler plant, and, it is understood, a large order for refractories for blast-furnaces and stoves has been placed with General Refractories, Ltd.

The order for the by-product coking installation has been placed with the Woodhall-Duckham Co. It will comprise a battery of 65 W-D. Becker coke-ovens, designed for heating by blast-furnace gas or coke-oven gas. The ovens will be capable of carbonising 1,370 tons of coal a day. In addition to the ovens, the contract includes a complete coal-blending, crushing and handling plant, a by-product plant for the recovery of tar and ammonia in the form of sulphate; crude benzole recovery plant, and plant for grading the coke and handling it to the blast-furnaces. About 1,000,000 gals. of benzole per annum will be derived from the coal.

The order for the boiler plant has been placed with Simon-Carvers, Ltd., and will include three Simon-Carves multiple-drum type boilers, each having a maximum continuous rating of 100,000 lbs. of steam per hour. Each boiler will be equipped with economiser, air-heater, and forced and induced draught fans. A feature of the design is the three systems of firing which will be employed. The boilers will normally be burning pulverised fuel supplied by Simon-Carves "Impact" pulverisers, but each will also be equipped with six Simon-Carves compound gas burners, designed for burning coke-oven or blast-furnace gas, or a combination of both. Large water-cooled combustion chambers of the Simon-Carves patent bare tube type will be provided on each boiler unit, and the contract also includes all auxiliaries within the limits of the boiler-house, boiler-house building, coal bunkers, chimneys, etc.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100 0 0

ANTIMONY.

English		£68 0 0
Chinese		54 0 0
Crude		26 0 0

BRASS.

Solid Drawn Tubes	lb.	10½d.
Brazed Tubes	,,	12½d.
Rods Drawn	,,	9½d.
Wire	,,	8½d.
*Extruded Brass Bars	,,	5⅝d.

COPPER.

Standard Cash		£44 7 6
Electrolytic		48 15 0
Best Selected		47 15 0
Tough		47 5 0
Sheets		77 0 0
Wire Bars		49 0 0
Ingot Bars		49 0 0
Solid Drawn Tubes	lb.	11¾d.
Brazed Tubes	,,	11¾d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0 3 1½
‡Ferro Tungsten	,,	0 3 0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
NOMINAL: 2–4% Carbon, scale 11/- per unit	ton	29 15 0
NOMINAL: 4–6% Carbon, scale 7/- per unit	,,	22 7 6
NOMINAL: 6–8% Carbon, scale 7/- per unit	,,	21 12 0
NOMINAL: 8–10% Carbon, scale 7/- per unit	,,	21 12 0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	,,	33 0 0
Guar. max. 1% Carbon, scale 12/6 per unit	,,	36 0 0
§Guar. max. 0·5% Carbon, scale 12/6 per unit	,,	37 10 0
‡Manganese Metal 97-98% Mn.	lb.	0 1 2
‡Metallic Chromium	,,	0 2 5
§ Ferro-Vanadium 25–50%	,,	0 12 8
§ Spiegel, 18–20%	ton	7 10 0
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	6 5 0
20/30% basis 25%, scale 3/6 per unit	,,	9 0 0
45/50% basis 45%, scale 5/- per unit	,,	11 15 0
70/80% basis 75%, scale 7/- per unit	,,	16 15 0
90/95% basis 90%, scale 10/- per unit	,,	28 17 6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12 5 0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 4½
Ferro Phosphorus, 20–25%	ton	22 0 0
§ Ferro-Molybdenum, Molyte	lb.	0 4 6
§ Calcium Molybdate	,,	0 4 2

FUELS.

Foundry Coke—		
S. Wales	£1 10 0 to	1 12 0
Scotland	—	1 10 0
Durham		1 4 6
Furnace Coke—		
Scotland	1 5 0 to	1 6 0
S. Wales	1 4 6 to	1 5 0
Durham	—	1 1 6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£68 0 0
*Commercial Ingots		49 10 0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0 0 9
*Cored Bars	,,	0 0 11

MANUFACTURED IRON.

Scotland—		
Crown Bars, Best		£10 10 0
N.E. Coast—		
Rivets		10 10 0
Best Bars		13 0 0
Common Bars		9 5 0
Lancashire—		
Crown Bars		10 10 0
Hoops	£10 10 0 to	12 0 0
Midlands—		
Crown Bars		10 10 0
Marked Bars		13 0 0
Unmarked Bars	from	9 7 0
Nut and Bolt Bars	£8 17 6 to	9 7 6
Gas Strip		11 7 6
S. Yorks—		
Best Bars		10 15 0
Hoops	from	11 7 6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	11½d.
†Sheet to 10 W.G.	,,	1/-
†Wire	,,	1/0¾
†Rods	,,	11d.
†Tubes	,,	1/2¼
†Castings	,,	1/0½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£4 5 6
Foundry No. 1	4 1 6
,, No. 3	3 19 0
N.E. Coast—	
Hematite No. 1	4 5 6
Foundry No. 1	4 3 6
,, No. 3	4 1 0
,, No. 4	4 0 0
Silicon Iron	—
Forge	4 0 0
Midlands—	
N. Staffs Forge No. 4	4 3 0
,, Foundry No. 3	4 9 0
Northants—	
Foundry No. 1	4 6 6
Forge No. 4	4 0 6
Foundry No. 3	4 3 6
Derbyshire Forge	4 3 0
,, Foundry No. 1	4 9 0
,, Foundry No. 3	4 6 0
West Coast Hematite	4 11 0
East ,, ,,	4 5 6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0.015, of phosphorus 0.025.
Per English ton .. .. .. Kr. 121

Billets, single welded, over 0.45 Carbon.
Per metric ton.. .. .. Kr. 265-335
Per English ton ..£13 17 6/£17 12 6

Wire Rods, over 0.45 Carbon.
Per metric ton Kr.315–365
Per English ton £16 10 0/£19 2 6

Rolled Martin iron, basis price.
Per metric ton Kr.210–230
Per English ton .. £11 0 0/£12 0 0

Rolled charcoal iron, finished bars, basis price.
Per metric ton Kr.310
Per English ton £16 5 0
f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£37 0 0
,, Braziery	34 0 0
,, Wire	—
Brass	23 0 0
Gun Metal	35 0 0
Zinc	9 10 0
Aluminium Cuttings	74 0 0
Lead	20 10 0
Heavy Steel—	
S. Wales	3 5 0
Scotland	2 17 6
Cleveland	3 0 0
Cast Iron—	
Midlands	2 15 0
S. Wales	2 14 0
Cleveland	3 5 0
Steel Turnings—	
Cleveland	2 5 0
Midlands	2 0 0
Cast Iron Borings—	
Cleveland	1 7 6
Scotland	1 18 0

SPELTER.

G.O.B. Official	—
Hard	£13 10 0
English	17 0 0
India	14 5 0
Re-melted	14 10 0

STEEL.

Ship, Bridge, and Tank Plates		
Scotland		£8 15 0
North-East Coast		8 15 0
Midlands		8 17 6
Boiler Plates (Land), Scotland		8 10 0
,, ,, (Marine) ,,		—
,, ,, (Land), N.E. Coast		8 10 0
,, ,, (Marine) ,,		8 17 6
Angles, Scotland		8 7 6
,, North-East Coast		8 7 6
,, Midlands		8 7 6
Joists		8 15 0
Heavy Rails		8 10 0
Fishplates		12 10 0
Light Rails	£8 10 0 to	8 15 0
Sheffield—		
Siemens Acid Billets		9 2 6
Hard Basic	£6 17 6 to	7 2 6
Medium Basic	£6 12 6 and	7 0 0
Soft Basic		5 10 0
Hoops	£9 10 0 to	9 15 0
Manchester		
Hoops	£9 0 0 to	10 0 0
Scotland, Sheets 24 B.G.		10 10 0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	,,	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to $\frac{3}{16}$ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£231 10 0
English	231 10 0
Australian	231 10 0
Eastern	232 15 0
Tin Plates I.C. 20 × 14 box	18/9

ZINC.

English Sheets	£26 10 0
Rods	28 5 0
Battery Plates	—
Boiler Plates	—

LEAD.

Soft Foreign	£24 1 6
English	26 0 0

*McKechnie Brothers, Ltd. Dec. 12. † C. Clifford & Son, Ltd., Dec. 12. ‡ Murex Limited, Dec. 12
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.
§ Prices ex warehouse, Dec. 12.